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Abstract Catalog

The abstracts in this publication are from original scientific research conducted by participating students in the 60th 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, U.S. Navy and Marine Corps, and U.S. Air Force and Space Force, and nationwide academic research institutes.

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60TH NATIONAL JSHS JUNIOR SCIENCE AND HUMANITIES SYMPOSIUM

Program Objectives

1. Promote research and experimentation in sciences, technology, engineering, and mathematics (STEM) at the high school level.

2. Recognize the significance of research in human affairs and the importance of humane and ethical principles in the application of research results.

3. Identify talented youth and their teachers, recognize their accomplishments at symposia, and encourage their continued interest and participation in STEM.

4. Expand the horizons of research-oriented students by exposing them to opportunities in STEM within the Department of Defense, academia, industry, and government.

5. Increase the number of adults capable of conducting research and development.

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ABSTRACTS OF STUDENT PAPERS

ALABAMA

The Local and Global Factors of the Generalized Poggendorff Illusions

Trisha Bheemanathini

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Mentor: Dr. Allan C. Dobbins, University of Alabama at Birmingham Biomedical Engineering Department

Perceptual illusions can be seen, interpreted and used in two aspects. The first is for recreation - to kill time, to entertain people etc. The second is to inform us about the nature of human perceptual processing. I plan to achieve such predictions by looking at the Poggendorff Illusion. The Poggendorff effect is a visual illusion in which two collinear line segments terminated by parallel lines appear to not be collinear. This 200-year-old illusion has many theories and hypotheses as to why the effect occurs but no concrete explanation has been found. Previous experiments involving moving the oblique either behind, in front, or in the plane of the central show that observers were most likely to report misalignment when the oblique line was in the plane of the object. My research involves adding a remote shadow to determine depth order to see whether a Poggendorff distortion is visible. 8 conditions were created, a left and right version of the regular Poggendorff, a left and right version of the naked Poggendorff, and 4 versions of the generalized figured Poggendorff with a triangle being the oblique line. Preliminary results neither refute nor verify conclusions but it shows that the ability the add a remote shadow to determine depth order and therefore, whether the Poggendorff distortion is visible, demonstrates that a local image processing theory is not sufficient enough to account for the Poggendorff effect, but does not rule out a role for local interactions in the representation of the junctions.

Ultrasonic Sight: Mindstorms® EV3 Wearable Device for Blind Navigators

Anna Bekah Cress

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Mentor: Jared Cress, Technology Service Corporation

Human Echolocation is a technique used by gifted blind individuals whereby they use sound waves echoing off of obstacles to inform themselves of their surroundings. This technique works similarly to RADAR and SONAR, and it allows them to navigate and function independently. However, the field of sensory substitution is a growing area in science which seeks to create technology that mimics the human senses. Until an artificial eyeball is created that can completely replicate human sight, or the means to correct optic nerves to completely restore a person's sight are obtained, there are other innovative ways in which to aid blind individuals who have not mastered the human echolocation technique.

The purpose of this project is to implement the principles of echolocation to create a wearable device which will aid blind users in navigating independently. For a first stage proof-of-concept prototype, this device uses EV3 ultrasonic sensors to detect obstacles in the environment. This device will be considered a success when I can efficiently navigate through different unknown rooms with obstacles at different levels while blindfolded and wearing the device. Future iterations could include wearability enhancements while remaining cost effective by leveraging commercial technologies such as automotive radar chipsets, which is a growing area to support advanced driver assistance systems, and active electronically steered antenna arrays.

How Distance Effects the Double Dip Transit Photometry Method's Ability to Detect Exoplanets

Makaila Jennings
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Teacher: Keelan Jennings

In our quest of whether there is life outside of our solar system, the focus has been on finding planets known as Super-Earths with Earth-like qualities suitable for life, but large enough for us to see. The purpose of this study is to see how distance affects the double-dip transit photometry method of detecting exoplanets. The procedure is to set up a star-planet system in a large four-foot black box with a color-changing and intensity-changing LED bulb to simulate the star. A Hot Jupiter (foam ball) is suspended from a rotating motor, orbiting close to the star, and a suspended Super-Earth (a bead) orbiting further from the star at three different distances.
Data was captured with a BH1750 light meter sensor connected to an Arduino Uno. Luminosity data was measured for each light color (red, yellow, orange, blue, and white) at high intensity with the motor running for the orbiting Hot Jupiter and pulley systems for the Super-Earth.
My hypothesis was proven correct that the distance of the Super-Earth from the Star and Hot Jupiter does affect the double-dip transit photometry methods' ability to detect exoplanets. The color of the star also affects the ability to detect exoplanets. It was easiest to detect the Super-Earth when the star was red, and the Super Earth was at its closest distance.

Glucose Mediated-Regulation on Suclg1, Pdk1, and Pdk4 Expression

Srijan Meesala
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Mentors: Luke A. Potter and Adam R. Wende

Over the last few decades, society has been facing a growing pandemic — diabetes. Diabetes is of major concern due to the types of health complications that result, involving greater risk for obesity, heart disease, and even stroke. Of these conditions, this study will focus specifically on diabetic cardiomyopathy, a disorder in the heart of diabetic patients that can result in heart failure. Of the many genes that play a role in energy regulation in diabetes, this study focuses on identifying a potential correlation between Suclg1, Pdk1, and Pdk4 expression and diabetic cardiomyopathy in mice tissue. Three cohorts were studied: mice that received streptozotocin (STZ), mice with cardiac-restricted GLUT 4 expression (mG4H), and untreated mice (VEH). The first two cohorts are hyperglycemic models that study when glucose uptake is increased and decreased. Both a qRT-PCR and a WesternBlot analysis were performed to determine changes in gene and protein expression of these three genes. The slight downregulation of Suclg1 suggests that deficiency in this gene decreases activity of an enzyme in the TCA cycle, attenuating ATP production. On the other hand, Pdk1 seems to be involved with issues with glucotoxicity and Pdk4 seems to be expressed when cells receive little to no glucose. Specifically, this study is the precursor for many future studies. Ultimately, it opens up further avenues in developing gene-specific therapeutics and potentially the role epigenetics play.

Glowing Gumballs: Can Gumballs Be Used as an Additive to Reduce Paints Flammability?

Julian Vilardi
Wetumpka High School, Wetumpka, AL

Purpose: To see if gumballs from sweet gum trees can be used as an additive in paint to reduce flammability.
Hypothesis: If I create a mixture of 20% gumballs, then the flammability will be lowered more than if there was 10% gumball ratio or no gumballs at all.

Procedure:

1. Collect the gumballs and acorns.
2. Cut the gumballs in quarters.
3. Remove the cupules of the acorn.

4. Put the gumballs into a blender and allow them to blend for 2 minutes, or until they are fine dust. Put the acorns into a blender and allow them to blend for 2 minutes, or until they are fine dust.
5. Set aside 24 cups.
6. Place the gumball and acorn dust into their proper cups.
7. Label 31 paint sticks.
8. Take a medicine measuring cup for each paint stick and create the mixtures for them.
9. Paint the bottom 2 inches of each stick with their proper mixtures.
10. Separate the sticks into groups based on the material painted on.
11. Allow them to dry for 2 hours.
12. One at a time, take a paint stick and place in in the fire. Start a stopwatch. Once the part of the paint stick with the mixture is completely burnt up, stop the timer. Record the time.

Results: The 20% gumball ratio for every single mixture caused the flammability to lower, making the sticks take longer to burn. The rest of the results were inconsistent.
Conclusion: My hypothesis was correct; the 20% gumball mixtures caused the flammability to lower.

ARIZONA

Comparison of Struvite and Chlorella vulgaris Solution to Phosphorus Water

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Agriculture fertilizer runoff contains high phosphorus concentrations, which directly correlates with eutrophication and, ultimately, has an adverse effect on ecosystems and organisms. Often overlooked, a practical solution to agricultural phosphorus pollution has not been explored. The objective of this study was to evaluate the effectiveness of Struvite (MAP) Recovery and *Chlorella vulgaris* Algae Growth as phosphorus filtration methods for agriculture runoff. Fertilizer water was collected from a local celery field in Yuma, Arizona and then treated with either Magnesium Chloride and Ammonium Nitrate to form Struvite, or with 10-day growth of *C. vulgaris*. Results indicate *C. vulgaris* as the most effective phosphorus filtration method when comparing initial and after-treatment phosphorus concentrations per trial. While the Struvite method removed 71.43% of the initial phosphorus, *C. vulgaris* removed 100% of the initial phosphorus for four out of five trials. Both methods have similar nominal value as each removed up to 1.0 ppm of phosphorus. The methods also show effectiveness in high and low phosphorus concentrations. The Struvite method decreased phosphorus concentrations for trials within a range of [0.6, 1.4] ppm of initial amounts. *C. vulgaris* Method decreased phosphorus concentrations for trials within a range of [0.4, 1.0] ppm of initial amounts. While *C. vulgaris* method is more effective than Struvite method, both filtration methods show promise in preventing phosphorus pollution while also benefiting agricultural systems as a fertilizer (Struvite) and the health supplement industry *(Chlorella).*

Self-Disinfecting High-Performance Facemask Based on Biomaterial Coated Nanofibers

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COVID-19 has caused more than 6,000,000 deaths worldwide, and face coverings are an essential line of defense against the virus. However, the commonly used surgical masks lack sufficient filtration efficiency, while N95 respirators are less comfortable to wear due to reduced breathability. Lacking self-disinfection functions, N95 and surgical masks are designed for single use, which strains the supply chain and produces unnecessary polypropylene waste that requires 20-30 years to decompose. Reusable face masks with the self-disinfecting function, high filtration efficiency, and easy breathability are in urgent need. The nanofiber-based self-

disinfecting face mask was designed to meet these needs. The nanofiber filters were created via electrospinning of polyacrylonitrile (PAN) solution, and then soaked in chitosan solution. The nanofiber filters, with a thickness of 10-20 micrometers, are sufficient to achieve the filtration efficiencies comparable to the much thicker N95 respirators, while maintaining easy breathability comparable to surgical masks for optimal wearing comfort. For self-disinfection against viruses and microbes, FDA-approved biomaterials including chitosan and epigallocatechin gallate (EGCG) were incorporated. EGCG was encapsulated into nanoparticles with above 90% efficiency for increased stability to bind electrostatically to chitosan. The EGCG nanoparticles and chitosan coated on PAN nanofibers demonstrate significant antimicrobial effects against *Salmonella enteritidis*, *Escherichia coli*, and *Staphylococcus aureus*, along with significant antiviral effects against Human Coronavirus OC43 that is used as a testbed of coronaviruses. The future application of these nanofiber filters being integrated into large scale production for highly efficient face masks with good breathability, self-disinfection function, and reusability looks promising.

AI-Based Wildfire Prevention, Detection and Suppression System

Prisha Shroff
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Wildfires pose a serious threat to the world's environment. The global wildfire season length increased by 19% and severe wildfires besieged nations globally. Every year, wildfires burn forests, causing vast amounts of carbon dioxide to be released into the atmosphere, contributing to climate change.

There is a need for a system which prevents, detects and suppresses wildfires.

The AI-based Wildfire Prevention, Detection and Suppression System (WPDSS) is a novel, AI-based solution that effectively detects hotspots and wildfires, and deploys drones to spray fire retardant, preventing and suppressing wildfires. WPDSS consists of four steps.

1. Pre-processing: Loads real-time satellite and meteorological data from NASA and NOAA of vegetation, temperature, precipitation, wind, soil moisture and land cover for prevention. For detection, it loads real-time data of Land Cover, Humidity, Temperature, Vegetation, Burned Area Index, Ozone and CO2.
2. Learning: AI model consists of a random forest classifier which uses a series of decision trees to make an accurate decision and is trained using a labeled dataset of hotspots/wildfires and not-hotspots/not-wildfires.
3. Identification: Runs real-time data through the model to automatically identify hotspots and wildfires.
4. Drone Deployment: Drone flies to hotspot and wildfire locations.

WPDSS attained a 98.6% accuracy in identifying hotspots and 98.7% accuracy in detecting wildfires. WPDSS will reduce the impacts of climate change, protect ecosystems and biodiversity, avert huge economic losses and save human lives. The power of WPDSS developed can be applied to any location globally to prevent and suppress wildfires, reducing climate change.

Evaluation of Gender's Effect in Predicting Parkinson's Disease from Voice Recordings: A Random Forest Approach

Shreya Sreekantham
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Parkinson's Disease (PD) is the second most prevalent neurological disease in the world, affecting more than 10 million people. It is characterized by a progressive loss of motor control, causing symptoms like tremors and impaired balance and eventually rendering the patient paralyzed and completely bedridden. PD has no cure, but an early diagnosis can help slow down the progression and improve the patient's quality of life. However, the diagnosis of PD is often subjective and inaccurate because its presentation varies widely between individuals of different demographics. One problem presented by this variation is that PD voice-based detection tools are often trained primarily with male voices, resulting in a lack of accuracy in diagnoses for women. This study focuses on predicting the progression of PD from voice recordings and evaluates the variation by gender using a novel Random Forest Algorithm (RFA). The algorithm utilized a multivariate dataset extracted from the UCI Machine Learning data repository that consisted of 5,875 voice recordings from 42 subjects. The RFA introduced in this study both improves the accuracy for PD detection and establishes that diagnostic algorithms can consistently perform well across gender (99% accuracy for females and 97% for males). In comparison, previous machine learning approaches when accounting for differences across gender achieved a highest accuracy of 82.14%. Additionally, this study identifies age and gender-based differences in the expression profiles of voice parameters that can be useful in future clinical applications.

Replacing Gallium Arsenide in Space Solar Cells with 2D Materials in a Novel 7-Junction Configuration

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Approximately 3 billion people have never used the internet due to its costs and inaccessibility, particularly in developing countries. To provide these areas with affordable internet, reducing the cost of building and launching satellites has become paramount in the assessment of their design, particularly their solar cells. While three-dimensional semiconductor materials like gallium arsenide (GaAs) have been the main material used in these cells to convert solar energy into electrical energy, two-dimensional (2D) materials like tellurene have demonstrated properties that warrant consideration. This research evaluates the potential of a novel 7-junction space solar cell configuration consisting of manganese phosphorus trisulfide, tungsten disulfide, rhenium disulfide, molybdenum disulfide, molybdenum ditelluride, bismuth oxyselenide, and tellurene to replace current 3-junction configurations using GaAs-based materials. Thermodynamic expressions, including the efficiency of a Carnot heat engine and a geometric optimization approach using the Shockley-Queisser triangle, were analyzed to derive equations for two properties critical to a space solar cell: efficiency and specific power. Computational simulations were run, and the results indicate that a 7-junction space solar cell configuration using 2D materials can enable a maximum efficiency gain of 12%, a mass reduction by over one-fifth, and a specific power output improvement of 54% at lower costs compared to GaAs-based space solar cells. The implications of this study point to the performance and cost feasibility of satellite usage for a broad range of applications, with social and environmental significance.

ARKANSAS

The Predictive Analysis of the COVID-19 Prognosis Using Machine Learning and Artificial Intelligence Techniques

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The COVID-19 pandemic has spread rapidly around the world, and it is currently one of the most leading causes of death and a major health disaster in the world. Due to the rapid spread and contagious nature of the COVID-19, medical professionals need to make informed decisions on how to diagnose and treat the disease effectively. The aim of the study is to design a predictive model based on machine learning and artificial intelligence techniques to predict the prognosis of COVID-19 and help medical professionals to choose the right course of treatment for their patients. In this study, data from Immune Epitope Database (IEDB), a freely available resource funded by National Institute of Allergy and Infectious disease, was used. This study provides a comparative analysis of different machine learning techniques, such as Support Vector Machine (SVM), K-Nearest Neighbor (KNN), and Random Forest, in predicting the prognosis and assisting healthcare providers with the prognosis of the COVID-19 patients. The results show that the Random Forest method performed better in predicting the diagnosis and prognosis of the disease. Early diagnosis will help healthcare professionals to make informed decisions at an early stage and will aid in understanding the disease progression that can help in treatment of the disease and to select the line of antibiotics that need to be used for treatment.

Change in Stress Symptoms After COVID-19 Vaccination in Middle and High School Students in Central Arkansas; A Community Survey

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COVID-19 pandemic has resulted in psychological stress in the population including children between 12-18 years of age. The COVID-19 vaccine was approved for that age group on May 10, 2021. More than 23 million eligible children have received at least one dose of a COVID-19 vaccine (5). This study aims to analyze the impact of the COVID-19 vaccination on the stress symptoms of middle and high school students. The null hypothesis is that COVID-19 vaccination has not significantly reduced the stress response. The survey consisted of eleven multiple choice questions with answers based on a scale of 1 to 5, with 1 being minimal change and 5 being significant change. The data collected included age, sex, and vaccination status. The respondents were divided into two groups, one fully vaccinated and other being partially vaccinated or unvaccinated. The mean response for students who were fully vaccinated was 2.41 and partially/non vaccinated students was 2.67. The p value was 0.61, which is not statistically significant. This study found that there was no statistically significant difference in stress response between fully vaccinated group and partially vaccinated or unvaccinated group. More studies should be conducted to assess the impact of vaccination in this age group.

Systematic Parkinson Audio Recognition Construct (SPARC): A Novel Approach Implementing A Machine Learning Method to Diagnose Parkinson's Disease Using Voice Features

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Medical Sciences (UAMS); Mr. Aaron Kemp, Lead Research Manager, Neurocognitive Dynamics Lab, Psychiatric Research Institute, University of Arkansas for Medical Sciences (UAMS)

Parkinson's disease (PD) is a neurodegenerative disorder primarily prominent in individuals 65 years and older (the *elderly population)*. Despite advances in the medical field, the diagnosis of PD requires examination in a clinical setting. However, due to the ongoing coronavirus pandemic in the United States (January 2020-present), requesting individuals to visit their local clinic can place them at potential risk for coronavirus. A literature search with Google Scholar and PubMed databases from January 2020 to January 2022 determined that currently, no machine learning model *(n=0/188)* has an accuracy of 90% or higher in predicting PD from vocal features. We propose our model SPARC, the Systematic Parkinson Audio Recognition Construct, a virtual diagnostic tool for the screening of patients with Parkinson's disease. Project SPARC consisted of the following steps: a) data collection, b) filter audio files, c) feature analysis, d) audio files to images, e) train a convolutional neural network (CNN), and f) determine which test is more accurate (*Ah* or *Rainbow passage*) to assist with PD diagnosis. By training a random forest algorithm to extract vocal biometric data for feature selection and a transfer learning CNN on waveform and mel spectrogram images, SPARC is a state-of-the-art model that identified vital vocal features in PD and determined that mel spectrograms and the *Ah* test are accurate identifiers for PD. Project SPARC is successful in providing an accurate and effective method for PD diagnosis (94% accurate) in a clinical or virtual setting through a vocal feature-based machine learning model.

Testing the Efficiency of Biological Charcoal to Fight CO2 Air Pollution

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Biological charcoal, or biochar, is an incredible substance that has the potential to mitigate climate change. While biochar is typically sold as a soil additive, it can also trap carbon dioxide in its incredibly porous structure. The hypothesis of this experiment was to determine if the efficiency of biochar in its typical use case was linear. This was tested using a carbon dioxide meter in an airtight container. In the container, biochar was tested 3 times per mass level, and three amounts in total (10 Grams, 20 Grams, and 30 Grams). The biochar was left in the container for 1 hour each test, and every hour 600 data points were collected using a Vernier LabQuest and carbon dioxide probe. For each group, the mean amount of carbon dioxide removed within the hour was calculated. Using 10 grams of biochar, 61% of the carbon dioxide was absorbed. Interestingly, increasing the amount of biochar in the container did not significantly improve the amount of carbon dioxide absorbed; rather, with the addition of more biochar, a smaller percentage of the carbon dioxide in the container was absorbed. This is seen as the 20-gram tests could remove 67% of biochar, and the 30-gram tests could only remove 71% of all CO2 in the container. This statistically insignificant difference most likely occurs due to the fact that not all of the biochar was exposed to oxygen at once. This shows that in its typical use case, in soil, biochar's efficiency at absorbing carbon dioxide would be greatly reduced, as only the top layer of biochar would be exposed to enough air. As a result, this experiment shows that if biochar is to be used as a combatant to climate change, it should be used in a quite spread out, well-ventilated area.

In Vitro Evaluation of the Antioxidant Potential and Differential Effects of Punicalagin in Normal and Breast Cancer Cells

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A growing area of research is focused on identifying drugs that have differential cytotoxic effects on normal and cancer cells. Pomegranate polyphenols are potent antioxidants and has anticancer properties. Punicalagin, the

major bioactive polyphenol has been reported to act as a tumor suppressor. This study was aimed to evaluate the differential effects of punicalagin on the cellular processes in normal and breast cancer cells.

The effects punicalagin (25 µM and 50 µM, 24 h) on antioxidant activity, protein expression of antioxidant enzymes and the transcription factor Nrf2, and TBHP-induced intra cellular reactive oxygen species (ROS) in normal cells (WI38) was measured by DPPH assay, western blotting and H2DCFDA assay. Anticancer effect, cell morphology and intra cellular ROS levels after punicalagin pretreatment (50 µM and 100 µM, 48 h) in breast cancer cells (MCF7 & MDA-MB231) were studied by MTT assay, light microscopy and H2DCFDA assay.

Punicalagin exhibited a dose dependent free radical scavenging activity. Pretreatment with punicalagin in normal cells showed significant elevation in the protein expression of antioxidant enzymes and Nrf2, and a significant decrease in the TBHP-induced intracellular ROS levels. On the other hand, punicalagin significantly decreased cell viability and increased intracellular ROS production in breast cancer cells but not in normal cells.

In conclusion, punicalagin demonstrated potent antioxidant capacity in normal cells. The ability to produce a differential response in the cytotoxic effects and intracellular ROS generation in normal and cancer cells provide preliminary evidences that punicalagin may be considered as a safe and effective anticancer drug.

CALIFORNIA NORTHERN & WESTERN NEVADA

Harnessing Neutrino Energy for a Sustainable Future

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Mentors: Lawrence Edmond, UC Berkeley Graduate; Ellen Torres Thompson, UC Berkeley Graduate

There is a growing need for sustainable forms of renewable energy sources that are efficient and cost-beneficial. Finding such energy sources is one of the critical challenges of the 21st century. This paper focuses on the prospects of using high energy particles abundant in the universe as a solution to the energy crisis faced around the world. The high-energy particle studied in this paper is the neutrino. Neutrinos are subatomic particles that are one millionth the size of an electron. They are of interest to physicists because they are present virtually everywhere, travel through regular forms of matter, and have exceptionally high energy levels. Neutrinos have ten billion electron volts when traveling freely across space, which is enough energy to break up the nucleus of an atom. Due to their high energy levels and eternal presence, neutrinos are a promising candidate for a renewable energy source. However, due to their minimal reactions with other forms of matter, it is difficult to harness their intrinsic energies. A panel that is capable of absorbing neutrinos can potentially produce substantial amounts of heat energy, which can then be converted into electricity. Energy from neutrinos is a great theoretical alternative and a clean source of energy for our planet and future generations to come. This paper takes another step forward in the mission to produce a primary source of energy that is green and sustainable for our planet.

A Physical Device to Help the Visually Impaired Read Money Using AI / Machine Learning in Third World Countries

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There are over 285 million blind people in the world, with approximately 87% of them living in developing countries. However, in third world countries, there is currently very little technology to help the visually impaired, especially with financial independence. In this report we present the Machine Learning algorithms used to develop the device to help visually impaired distinguish between different forms of currency. Throughout this process, we tried the following approaches: the Google Vision API, Binary Classification,

Filtering Data, KNN Feature Detection, and Transfer Learning. The final model used transfer learning, which had both the ability to work without the use of public WiFi and had a very high accuracy. The code for these various approaches can be found in the "References" section of the report. Using the various currency images, we formed a dataset that was able to test and identify the accuracy of these algorithms. Experimental results show over 94% accuracy with the Transfer Learning Model. The device is designed to be portable and hand-held. The device can distinguish between 1, 5, 10, and 20 dollar bills. Additionally, it can work in the absence of the Internet. Overall, the device is cost effective, portable and can be used in the absence of internet connectivity.

A Novel Deep Learning/Machine Learning Hybrid Technique for Automatic Classification of Nebulae

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Mentor: Nisha Talagala, AI Club

There are believed to be ~20,000 nebulae in the Milky Way Galaxy; however, humans have only cataloged ~1,800 of them even though we have gathered 1.3 million observations. Resources like the Hubble telescope can automatically explore space and discover new artifacts. Still, their classification is a human skill, which ultimately is interminable and subject to human error. The importance of classifying nebulas cannot be stressed enough. Studying the chemical composition of a nebula can help us understand the material of the original star. My research of nebulae classification aims to make the process of discovering and classifying new nebulae faster and more accurate using a hybrid of Deep Learning and Machine Learning techniques. Nebulae can be classified into five different categories: planetary, supernova remnants, emission, reflection, and dark. Using a dataset primarily of images from the European Space Agency, I experimented with a range of artificial intelligence techniques and determined the deep learning network/machine learning algorithms that produced the best results. Some experiments included converting the images to black and white, featurization, and dropping specific categories. The main conclusions reached from my research were that the AI was not dependent on color to classify nebulae, dropping specific categories increased accuracy and that featurization is the most effective technique to classify nebulae accurately. The discovery of new astronomical bodies is already mechanized. Making the classification of nebulae automated will help us discover, identify, and classify these marvels much faster and accurately.

Mixup-VQ-VAE: A Novel Image Augmentation Technique for Clinical Machine Learning Applications

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In many applications of clinical machine learning, available datasets may not be sufficiently large enough to train generalizable supervised machine learning models. To improve the generalizability of supervised machine learning models in clinical machine learning applications, Mixup-VQ-VAE, a novel data augmentation mechanism that recombines samples in the latent space of a Vector-Quantized Variational Autoencoder (VQ-VAE) using Mixup, a convex interpolation technique, is proposed. Performance of deep neural networks trained on Chest X-ray medical imagery, augmented with Mixup-VQ-VAE and other computer vision data augmentation algorithms, are compared. It was observed that Mixup-VQ-VAE improves the test accuracy of ResNet-50 on this task by 18% over the same model trained on non-augmented data, highlighting the efficacy of this augmentation mechanism for clinical machine learning applications.

Accessible, AI-Enabled TeleMedicine Solution for Multi-Organ Dysfunction Caused by SARS Infections

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Mentor: Mr. Stephen Dunifer

There are currently about 455 million SARS infections worldwide with 24% of these cases being severe and a 2% mortality rate due to late medical attention. SARS patients have common symptoms of Multi-Organ Dysfunction (MOD) which include: fatigue, difficulty breathing, and fever. Delay in the detection, diagnosis and treatment of MOD indicators can lead to the inability of managing severe symptoms, conditions worsening, and even deaths that can be prevented. The spirometer, oximeter, and thermal camera are the devices that measure these defined symptoms and were utilized in this solution to output correlative analysis. Code developed in C with the Arduino IDE is used to develop the correlation algorithm to output an "Overall Health" reading for the user to interpret. Integration of these vital elements led to a contactless telemedicine device that can display comprehensive data/results along with the use of IoT and Machine Learning. Lung Capacity, Oxygen Saturation, and temperature reading had an inaccuracy of approximately 1-5%. The correlative analysis along with predictive analytics powered by AI/ML algorithms implemented, provides a precise overall health reading for users to apprehend. With the compact and affordable design of integrating the 3 biotechnologies onto a single board, we can leverage this to be accessible for low-income, senior citizens and underserved communities to ensure equal healthcare access opportunities to all people in our societies. In addition, a more sustainable flow of ICU admissions can be achieved because users will have real-time data on their state of being. This leads to a proper triage process when users will see a trend of their overall health decreasing and go to the hospital to seek medical attention.

CALIFORNIA SOUTHERN

Modeling Calcium Influxes Through Neuronal Synapses Highlighting NMDA Receptors

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Mentors: M. Bell, J. Laughlin, and C. Lee, Rangamani Lab, Department of Mechanical and Aerospace Engineering, University of California

Dendritic spines are small, membranous protrusions from a neuron's dendrite which are the hub for receiving signal inputs from axons at areas called synapses. The synaptic plasticity, or strength, of a synapse depends on its ability to perform synaptic signaling through second messenger Calcium ions. Ionotropic membrane receptors, such as N-methyl-D-aspartate receptors (NMDARs), located on the post synaptic cell play a key role in Long Term Potentiation and Depression affecting the memory retention of cells. To consider the effect of NMDAR on calcium dynamics, varying parameters, blocked Magnesium ion concentrations in NMDARs, membrane voltage and extracellular calcium concentrations, were used to model calcium dynamics mathematically. Ordinary differential equations were used to solve the system of equations which looked at a calcium influx with a timescale of 20 milliseconds. Using this model, we were able to focus on how important these specific parameters were in regulating the rate of flow of calcium ions into the post synaptic cell. The results indicated that with increases in the concentrations of Magnesium and extracellular-calcium ions, and probabilities of opening receptors, there was an overall increase in the rate of flow of calcium ions into the cell. To implement the results on a 3D model, realistic geometries of dendritic spines were created through the smoothing of meshes. Then, the ODE model of calcium influx through NMDAR can be converted to a full spatial, PDE model in these realistic 3D geometries to allow for a visual representation of the diffusion of calcium ions in dendritic spines.

"Minimally Calibrated High Performance Communication Interfaces for the Neurologically Impaired": New Directions Using Language Models

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Mentor: Professor William Speier, University of California, Los Angeles

Amyotrophic lateral sclerosis is a progressive neurodegenerative disease involving motor neurons in the cerebral cortex severely impairing patient's lives. P300 speller-based brain computer interfaces (BCI) provide an alternate communication medium based on subject' EEG response to characters on a highlighted flashboard. Alternatively, in paralyzed patients, implanted electrodes capture brain neural activity which are then algorithmically interpreted with machine learning techniques.

However, in all these BCI's, communication speed is severely affected due to poor system design choices. Further, they also require extensive calibration on a subject-by-subject basis. Drawing from diverse areas such as speech/language processing and data compression, this cross-disciplinary research presents multiple high-efficiency state-of-the-art BCI systems along with low-cost therapeutic gaming applications. Redundancy in human communication is exploited with powerful multi-level language models along with a smoothing technique to account for predicting out of vocabulary characters and words. Probabilistically optimized BCI flashboards and scanning including a new Huffman scanning scheme inspired by data compression are designed and analyzed. Using extensive simulations with multi-subject EEG data, speed improvements of almost 40% using word prediction based on partial and prior words are demonstrated in noninvasive BCI systems.

Subsequently, a state-of-the-art invasive "typing without hands" BCI system is demonstrated. More specifically, a paralyzed subject's imagined handwriting is deciphered directly from neural signals from implanted sensors using AI algorithms and converted to text on screen. Further, calibration requirements are minimized by augmenting training with public handwriting datasets and a very high accuracy of almost 87% is obtained.

AURA: A Novel ResNet50 Approach to Predicting Karnofsky Performance Score (KPS) and Survival Time of Glioblastoma Patients

Diya Sreedhar
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Teacher: David Kim

Glioblastoma (GBM) is an incredibly aggressive brain cancer, accounting for nearly half the number of malignant brain tumors each year. With one of the lowest five-year survival rates of all cancers (only about 6.8%), GBM has proved to be a challenge for doctors to treat and diagnose. This project leverages artificial intelligence to predict GBM disease progression with the metrics of survival time and Karnofsky Performance Score (KPS). After comparing several state-of-the-art neural networks, ResNet50 was determined to have the highest predictive performance for these measures of GBM disease progression. The most effective hyperparameter configuration and optimizer were found to increase model accuracy. The survival time and KPS ResNet50 models both scored a training accuracy of 100% and testing accuracies of 85.67% and 82.43% respectively, reaching accuracies previously unseen by other GBM predictive progression models. The models were finally integrated into the mobile app AURA, which displays patients' personalized GBM prognosis and provides end-of-life care resources. Inexpensive and highly accessible, AURA is a high-fidelity prototype that brings essential resources to every GBM patient. AURA can help patients plan their treatments, as the information on disease prognosis it provides can be used to organize intervention and prepare the best care for the patient.

The Integrity of Fecal Microbiome Biospecimen Diversity and Composition across Temperatures and Time points

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Mentor: Dr. Ying Taur, Memorial Sloan Kettering Cancer Center

The intestinal microbiome continues to be a growing area of research with potential benefits in human health. Studies involving collection of fecal specimens from human subjects usually employ collection protocols aimed at preserving microbial composition during storage of samples and subsequent DNA sequencing. These protocols dictate parameters such as the allowable time between collection and freezing, so as to minimize chances of alteration of the microbial populations and degradation of bacterial DNA. However, these guidelines vary greatly, and currently there is little consensus as to how long samples can truly be stored. In this study we sought to concretely examine the degradation of samples by evaluating the integrity of the gut microbiome in fecal specimens at different temperatures (-80°C, -20°C, 4°C, room temperature) across several time points (0, 3, 8, 11 days) after collection. Specimens were analyzed by 16S rRNA gene sequencing and curated using the DADA2 pipeline. For each sample, alpha diversity and microbial composition were assessed and compared. A total of 11,062,741 16S sequences across 26 samples were obtained. Linear discriminant analysis effect size was used to assess the effects of storage time and temperature on degradative changes to the sample. Notably, we found that bacterial diversity and composition remained relatively the same across all conditions. We conclude that the parameters for human fecal sample collection could potentially be relaxed in terms of allowable storage time and temperature. This may help to improve the practical feasibility of microbiome studies involving sample collection from human subjects.

CONNECTICUT

Development of a Home N-Terminal Pro-Brain Natriuretic Peptide Assay for Early Detection of Congestive Heart Failure

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Mentor: Dr. Stuart Zarich, Bridgeport Hospital/Yale New Haven Health

Congestive heart failure (CHF) affects millions of patients and is associated with a high mortality rate. Early detection and treatment can improve outcomes and avoid hospitalization, but it is often difficult to tell if symptoms are specifically due to CHF or another cause. N-Terminal Pro-Brain Natriuretic Peptide (NT-proBNP) is an excellent biomarker for CHF. The lateral flow assay (LFA) is a technology that can be adapted for use as a home test. A NT-proBNP assay was created using a universal LFA kit with the appropriate capture and detection antibodies. Recombinant NT-proBNP was used to test the assay at varying concentrations. NT-proBNP was readily detectable using this system and the visual bands on the LFA strips were quantified using an optical densitometry protocol. After optimization of the reagents, NT-proBNP levels down to 5,000 pg/mL were detectable. This puts the test in the range of NT-proBNP levels that have been described for patients hospitalized with CHF. This test was repeated with purchased human serum spiked with recombinant NT-proBNP and demonstrated detection at similar concentrations. The results of this experiment were shown to 20 blinded volunteers who were able to detect the positive test lines of NT-proBNP concentrations of 5,000 pg/mL and higher. These results show that a home NT-proBNP test is feasible and could be used for early detection and treatment of CHF.

Evolutionary Responses to Climate Change in a Long-Distance Migratory Songbird: The Scarlet Tanager

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Mentor: Dr. Maggie MacPherson, Louisiana State University Museum of Natural Sciences

In the 21st century, as the climate changes rapidly, many species are left with the uncertainty that their evolutionary processes may not keep pace. Profound consequences will result from the human population's heavy reliance on the environment, so it is vital to protect species. In this study, a migratory bird species known as the Scarlet Tanager's *(Piranga olivacea)* vulnerability to climate change was assessed in terms of its breeding range and morphology. *P. olivacea's* geographical dispersion was projected and analyzed using the Species Distribution Model "Maxent". Locality data for models was obtained from the Global Biodiversity Information Facility (GBIF) from 2000-2020, and April-October in North America. The WorldClim database was used for environmental data to assess *P. olivacea's* relationships with minimum and maximum temperature and precipitation, factors impacted by climate change. WorldClim's future climate data (under RCP 8.5) until 2070 was used to evaluate the Tanager's future vulnerability. Morphological data from LSU's Museum of Natural Science was utilized to examine *P.olivacea's* morphological evolutionary development. It was hypothesized that *Piranga olivacea* will attempt to shift its breeding range and morphologically adapt to changing climatic conditions, but ultimately the species's ability to do so will prove limited. Yet, the findings suggest that minimum temperature is the largest limiting factor in *P.olivacea's* breeding range, and thus *P.olivacea* has the potential to expand its range past historical northern limits as temperatures rise. Findings additionally suggest that *P.olivacea* may be selecting for blunter wings for travel through dense forest habitats, as well as decreasing its tail length to accommodate for longer migrational distances.

JARVITS: A Novel Deep Learning IoT Traffic Control System for Real-time Detection and Signal Optimization

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Mentor: Dr. Hyung Gi Min, Adjunct professor at Namseoul University

In the status quo, traffic signal control systems operate on predetermined patterns and instructions devised from past data. While this method functions effectively for traffic under normal conditions, it becomes heavily congested and inefficient during rush hour. Furthermore, the constant presence of unexpected emergencies renders pre-determined systems ineffectual. By combining traditional traffic controllers with modern technologies like Internet of Things (IoT) devices and computer vision, traffic control systems can be greatly improved. Yet there are currently no systems that can affordably fulfill this task.

By optimizing traffic signal duration, this allows for both a reduction in delay time for vehicles and a reduction of greenhouse gases emitted. Considering the Intergovernmental Panel on Climate Change's August 2021 report on the current dramatically worsening state of the climate crisis, there is a compelling need for such a traffic control system to optimize throughput and thus greatly reduce vehicle's greenhouse gas emissions.

This research presents a novel deep learning traffic control system, called JARVITS (Just A Rather Very Intelligent Traffic System) that can be used for accurate real-time vehicle detection and signal control. Compared to previous methods, JARVITS offers a complete solution, with a physical vehicle detection algorithm and traffic signal optimizer. This study can largely be divided into two subsections: (1) the IoT traffic control system and (2) traffic control optimization. Lastly, a realistic virtual simulation created using Pygame is used to model traffic conditions and demonstrate that this research effectively improves traffic flow for an intersection.

Cloud Identification in Mars Daily Global Maps with Deep Learning

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Mentor: Scott D. Guzewich, NASA Goddard Space Flight Center, Greenbelt, MD

Cloud identification on Mars is an important tool for climatology studies, making it possible to analyze the distribution, patterns and variability of clouds both spatially and temporally. Traditionally, cloud data on Mars has been extracted through manual or semi-automated processes which can be time consuming, and currently there is limited spatial and temporal cloud data coverage. In this paper we demonstrate the successful use of convolutional neural networks (CNNs) to extract cloud masks from Mars Daily Global Maps (MDGMs) composed from the Mars Color Imager (MARCI) on the Mars Reconnaissance Orbiter (MRO). The fully automated model reports 97% pixel-wise accuracy compared to the testing dataset, and in many occasions the model performs better at extracting the full extent of the cloud compared to the prior semi-automatic technique. We also introduce several image pre- and post-processing techniques to improve the model's performance and usability. The model is configured to provide cloud masks at 0.1° longitude by 0.1° latitude resolution. It also automatically bounds the MDGM by northern and southern polar extents depending on solar longitude. The results suggest that our deep learning model is a useful tool to automatically and quickly extract Martian water ice cloud masks and make it possible to generate cloud mask data across the complete set of MDGMs and future ones. The model and related techniques also have potential extensions to Martian dust storm identification. We will make our code, model, and data publicly available.

Ferro-Sponge: An Investigation into the Usage of Metal Oxides for the Removal of Microplastics and Oil from Water

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Mentor: Ms. Anne Gold, Product Development Specialist, 3M Personal Safety Division

Many water sources currently contain hazardous microplastics and oils, for which efficient removal methods do not yet exist. I have performed extended research over several years developing methods to address this issue, the latest of which is presented here.

Current research tested the implementation of electromagnetic filtration aided by contaminant agglomeration induced by metal oxides – Fe_3O_4, MnO_2, and NiO, of which Fe_3O_4 was most effective. Fe_3O_4 nanoparticles were consequently synthesized to increase the surface area for agglomeration, thus increasing microplastic removal. Due to their properties as sorbents, it was hypothesized that they were capable of also removing oil from water. The nanoparticles were proven to be more effective than general Fe_3O_4 particulate. However, aiming for an efficient implementation on larger scales, these nanoparticles were adhered to a polyurethane sponge, the original "Ferro-Sponge" model. Three other additives were tested to increase the model's effectiveness: bentonite, a clay compound with known oil removal capabilities; sorbent pads, expected to absorb oil; and mineral spirits, expected to increase Fe_3O_4 nanoparticle retention via adhesion promotion. Only bentonite effectively enhanced the removal of these contaminants in water. The final "Ferro-Sponge" model was created by coating a polyurethane sponge in a mixture consisting of synthesized Fe_3O_4 nanoparticles and bentonite. All testing was done by using home-built and laboratory spectrometers, and a microscope.

To measure real-world effectiveness, contaminated water from Long Island Sound was treated with the "Ferro-Sponge," in which the "Ferro-Sponge" successfully removed contaminants. The "Ferro-Sponge" is currently patent-pending and in contact with industrial companies for implementation.

DODEA EUROPE

Mobile and Multicultural Aspects of Adolescent Identity Development

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Teacher: Daniel Coapstick

As mobility and multicultural exposure become increasingly prevalent in the globalized world, it becomes more important to understand their effect on how people view themselves and their place in society. Mobility and multicultural exposure have a significant impact on adolescent identity development. The purpose of this study is to investigate how these two factors influence the way adolescents approach identity development and to connect these approaches (identity processing styles) to specific aspects of mobile/non-mobile and multicultural/non-multicultural backgrounds. First, the connection between mobility, multicultural exposure, and identity processing styles is analyzed using the responses of participants-- of varying mobile and multicultural backgrounds-- to a demographics survey and the Identity Style Inventory 5 form. Then, interviews are conducted in order to obtain a more detailed picture of participants' background. Mobility was found to have a significant correlation to identity style, with increased mobility leading to a more purposeful, open minded approach. It was also found that the introduction of mobile and multicultural factors into a person's life leads to a more diverse, less predictable approach to identity development. This reflects the diversity of this group and the more turbulent identity formation process. Overall, there is a need for further research on identity formation in highly mobile and multicultural adolescents to identify the cause of diversity in identity approaches, and to find better ways to aid this demographic. This research is particularly relevant to this demographic in childhood and adulthood, as well as their caretakers, teachers, and healthcare providers.

Chasing Bread Crumbs: How Sharing Seemingly Irrelevant Information May Prove to be a Vulnerability

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Operations Security (OPSEC) is a crucial procedure in the military to protect sensitive information. Compromise of this information is detrimental to the military and its families. Indicators provide clues as to what the critical information (CI) is and oftentimes indicators are present on open source platforms. The purpose of this student is to evaluate the vulnerability of current affiliates with the military on the social media platform LinkedIn. LinkedIn prompts the user to provide and publish their own personal information, which may serve as indicators for an adversary. Through the means of a web scraper, this data will be extracted and evaluated by a scoring system based on the OPSEC process.

Analysis of a Radial-Flux Eddy Current Brake Incorporating a Halbach Array

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SHAPE American High School, Mons, Belgium
Teacher: Jason Neago

Eddy current braking (ECB) technology has many advantages over conventional friction brakes, including less wear, faster activation time, and intrinsic properties similar to anti-lock braking mechanisms. To improve ECB performance, the possible torque output should be increased to decrease braking time and enable heavier loads. To accomplish this goal, the magnetic field of the ECB should be altered and strengthened. A design for an ECB incorporating a Halbach array with 3 pole pairs was proposed with 24 discrete magnets, and compared to a design using alternating magnetization directions on the same 24 magnets. Their output torques were measured across the speed range from 250-1500 RPM using Finite Element Analysis. The deceleration of each design was also measured over 0.02s starting at 1000 RPM. The ECB using the Halbach array was found to produce greater torques than the alternating design at 750 RPM and below, and the alternating array produced higher torques for angular speeds 1000 RPM and above. This, however, contradicts the deceleration data, which showed the

Halbach ECB dissipating more kinetic energy at 1000 RPM than the alternating design. This contradiction made conclusions on these datasets impossible to any practical specificity. However, the eddy current density, and magnetic flux density created in the brake disk was also recorded, showing that the Halbach ECB created fewer eddy currents with stronger electrical current, while the alternating ECB created more numerous eddy currents with weaker electrical currents.

How Does Depth Perception Play a Role in Serve Percentage?

Teven McCarthy
Sigonella MHS

In this research project, the researcher sought to find out how big of a role depth perception played in volleyball; more specifically the "serving" aspect. They wanted to test if the control results of the standard, unassisted serves are near or equal to the results of the serves with depth assistance. If that was true, then the added bulletin board would help with depth perception, as well as serve percentage. To test this, they gathered a group of seven volunteers from their high school volleyball team and asked them to serve ten times each how they would do it in a real game setting. The researcher then added a bulletin board on the far boundary line and asked them to serve the same amount of times once more. The results showed a significant increase in serve percentage, proving that this assisted their depth perception during the serve. They then removed the bulletin board and had each volunteer serve ten more times. Despite the results being lower than the serves with the bulletin board, they were much higher than the original serves. This proved that practicing with the depth perception assistance had long lasting effects on the volunteers' serve percentage. This experiment proved how large of a role depth perception plays in serve percentage.

"Volunteering Abroad: For You or for Me?": An Evaluation of Voluntourism Companies Performances Through Examining the Relationship Between Recipient-Centered Objectives and Expenses

Olivia Morrow
Spangdahlem High School, Spangdahlem, Armed Forces Europe
Teacher: Matthew Cirillo

The voluntourism market is a profitable niche within the tourism industry, and that follows a close critique to the practice of volunteering abroad. The researcher aims to analyze the nature of voluntourism companies in the way they spend their money and what their objectives are, in order to evaluate volunteer trips. The researcher wanted to find out if the companies studied were giving more or less money than they were indicating they were in their objective statements by grading the companies. The researcher obtained financial reports from seven volunteer abroad companies and put those finances into percentages, based on if the expenses went to the volunteer, recipient, or neutral. They coded the objective statements of those volunteer abroad websites, coding them through a coding system of 84 words, into the same categories volunteer-centered, recipient-centered, and neutral. From that, the researcher took the percentages of language and expenses and put them into a linear regression. They then found the residuals of each individual data point. They found that most of the companies fell below a C grade, or the average grade of all the companies relative to each other, on the grading scale for recipient-centeredness objectives and expenses. This brought evidence for the idea that voluntourism operations are becoming less recipient-centered, despite it being one of the most popular motives to "help a community abroad." The researcher hoped to bridge the gap between recipients and the voluntourism company operators, in making the voluntourism experience an enabling endeavor for everyone involved.

DODEA PACIFIC

How Does the Prevalence of Gender Stereotypes Differ Amongst Age Groups?

Chloe Bogen
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Sponsor: Mr. Charles Strobino, Nile C. Kinnick High School

An experiment was conducted to see whether gender bias varied between generational age groups. Stereotypes have long been apparent in society, even at the beginning of human evolution. As a consequence of the male's higher reproductive rate, a disparity between parental investment emerged (Geary, 2000; Archer 2009), and men developed a higher affinity for risk-taking and aggression due to competition to find a female partner. Women came to be more dependent and risk-avoidant as they did not face this competition (Archer, 2009; Puts, 2010). Their role of having children, and therefore pregnancy, breastfeeding, and childcare put them at a disadvantage when participating in economic activities (Wood and Eagly, 2012). Stereotypes emerged as a response to these roles. However, recent movements for equality and the internet have spread awareness about the harmful effects of this bias. In this study, it was hypothesized that gender stereotyping has changed throughout different generations, and that the significance of stereotyping would be less in a younger age group (14-19) than two older age groups (20-39 and 40-60, respectively) in the categories of occupation, personality traits, and domestic behaviors. An analysis of the results did support the hypothesis. Overall, the youngest group displayed the most occurrences of having the least bias.

Optimizing Artificial Reef Structures for Japanese Marine Industries

Claire Bogen
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This project conducted a meta-analysis of the past and current use and workings of artificial reefs. Further analysis was given to the criteria a structure would need to be advantageous for use in Japan. According to research, artificial reef structures should have the ability to alter surrounding water velocity levels, the ability to alter surrounding pressure levels, and should have a larger percentage of non-horizontal spaces compared to horizontal spaces. Furthermore, a successful reef should have a high number and volume of shadowed hollow areas mimicking caves/crevices. Based on this research, an optimized design was created and tested against two commonly used artificial reef designs: a tire reef and a standard concrete cube reef. It was hypothesized that the structure specifically designed for use in Japan would perform better in 5 tests deemed crucial to an artificial reef's success in Japanese waters. Computer simulations and mathematical analysis were performed on the reefs and results were then compiled. The results of the designs were ranked 1-3 for each test and entered into an anova calculator. The hypothesis was accepted. The specialized design performed better than other designs ($p = .000017$). Implementation of this reef would be an efficient means to increase biomass and benefit the ecosystems that live off the coasts of Japan.

The Effect of Window Position and Air Conditioning on Car Ventilation

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Sponsor: Mr. Adam Mitchel, DoDDs

Viral diseases including SARS-CoV-2 spread via airborne particles carrying contagious pathogens that an infected individual can release when coughing, sneezing, speaking, and breathing. Good ventilation is important to mitigate the spread of such diseases. This experiment aimed to determine which combination of car conditions, specifically windows down or up and AC on or off would result in the best ventilation. These conditions were tested in a small car with two people using carbon dioxide sensors measuring carbon dioxide levels over ten minutes as an indication of quality of ventilation. By comparing carbon dioxide levels in four test

conditions to established ventilation guidelines, this experiment concluded that when car windows are open ventilation is good, however when car windows are closed ventilation is poor, especially when the AC is off, putting individuals at increased risk of possibly transmitting viral diseases. Implementation of these findings into driving practices during the current pandemic, specifically for individuals carpooling or using rideshare services, could lower the possibility of SARS-CoV-2 transmission.

The Impact of Various Water Irrigation Systems on the Biomass Production of *Triticum aestivum*

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Some studies have shown that damaged irrigation and drainage systems of agricultural nations have caused water-build up and increased soil salinity, which hinders plant growth and decreases crop production. To identify how irrigation systems impact the growth of crops, a study was conducted testing the growth of *Triticum aestivum* with three irrigation methods: canal irrigation (control), drip irrigation, and subsurface irrigation. It was predicted that *Triticum aestivum* grown with experimental methods will have a biomass production 30% higher than that of wheat grown with the control method. Three planting containers were prepared with different irrigation methods each. In each container, a total of 30 *Triticum aestivum* seeds were planted. The plants' height, germination rate, and biomass production was recorded over a period of 3 weeks. The canal, drip, and subsurface irrigation systems had biomasses of 0.64 g, 1.78 g, and 1.6 g respectively. The difference between the control and experimental groups were statistically significant. Drip irrigation had the highest plant height average, germination rate and biomass. These results supported the hypothesis and showed that drip irrigation can be a highly effective method, especially in areas with dry and salinized soil, such as Iraq.

Measure of Bacterial Cell Damage from Microwave Radiation Compared to Conventional Heating as Seen on *Escherichia coli* and *Staphylococcus aureus*

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Teachers and Sponsors: Jillian Eastman, Jacob Brookover, and Lonnae Calvin

The effect of non-ionizing radiation on cell growth remains a topic of debate given its ubiquitous use in everyday electronics and appliances. Microwaves in particular are commonplace for cooking and in communication devices such as cell phones. However, it is not well delineated if microwaves directly cause cell damage or if the cell damage is indirectly related to the heat that generates exciting water molecules. To elucidate any additional effect that microwaves may have on bacteria growth, both a Gram-positive bacterium, *Staphylococcus aureus*, and a Gram-negative bacterium, *Escherichia coli*, were subjected to conventional heat from a hot plate and microwaves to determine if there was any detectable difference in growth at comparable temperatures. For comparison, the same bacterial concentration in normal saline was subjected to 10-second intervals in a 700-watt microwave with the temperature and quantitative culture taken at each interval until boiling. This was compared to the same bacterial solution subjected to conventional heating where quantitative cultures were taken at the same temperature as recorded during each microwave interval. Results showed no significant difference between the decrease in growth of both *E. coli* and *S. aureus* between conventional heating and microwaving ($p = 0.118$, $p = 0.061$ respectfully) although the microwave arms trended toward sterilizing more quickly than conventional heat. There also seemed to be a different sterilization effect for both the Gram-positive isolate as compared to the Gram-positive isolate despite inherent differences in their cell membranes.

FLORIDA

Assessing the Sensitivity of *Acropora cervicornis* Resulting from Exposure to Polycyclic Aromatic Hydrocarbons

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Coral reefs play an important role in marine ecosystems; protecting coastlines from flooding, and supporting more species per unit area than any other marine ecosystem. These unique ecosystems are in danger because of environmental pollutants that seep into the oceans, killing susceptible coral. This research investigates the effect of chemicals with long residence time on coral health.

Using NOAA's National Status and Trends Data to identify which pesticides, insecticides, herbicides, and metals have been found in coastal Florida water and sediment samples, I collected data on the types of chemicals and their prevalence. Coastal locations containing declining coral reef ecosystems were analyzed by which chemicals were found to be in the highest concentrations and the source of the chemical exposure.

The most common types of chemical in each location were polycyclic aromatic hydrocarbons (PAHs), known to enter the oceans through offshore drilling, close to the oceanic locations with the highest concentrations of PAHs. I then tested the effect of fluoranthene (a PAH), on an endemic species of coral, *Acropora cervicornis*, found in Florida's marine ecosystems, using 24 dosing vessels each containing 3 fragments of coral. Silicon O-rings, a passive-dosing method, were used to achieve accurate concentrations. I used semi-quantitative scoring and PAM fluorometry to assess the sublethal stress of fluoranthene using 6 increasing concentrations to determine the chemical's EC-50 and LC-50.

I determined that fluoranthene has no significant effect on *Acropora cervicornis* without UV light, as it is a phototoxic chemical which requires UV light to produce a deleterious effect.

Analyzing the CD44-Targeting Capabilities of Chitosan-Coated Iron Oxide Nanoparticles in Glioblastoma Multiforme

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Mentor: Dr. Atique Ahmed, Northwestern University Department of Neurosurgery

Glioblastoma Multiforme (GBM) is the most common type of malignant brain tumor, and it is especially lethal with a median survival of only 21 months. It is characterized by an extremely strong recurrence rate (close to 100%) which is partially caused by resistance to conventional therapies. Cancer Stem Cells (CSCs) are a subpopulation of cancerous cells that are highly proliferative and drive tumor metastasis, recurrence, and therapeutic resistance. CSCs can be identified by certain stemness- related cell surface proteins which are distinguishable via flow cytometry. CD44 is one of the most common stemness markers. This study examines the efficacy with which chitosan-coated solid core iron oxide nanoparticles target CD44 in highly malignant GBM cells, thus providing valuable insight into a viable option for the direct and specific treatment of the most dangerous form of brain tumor cell. Chitosan-coated iron oxide nanoparticles were synthesized using a co-precipitation method and characterized via dynamic light scattering to show optimal characteristics for neurological applications. GBM6 cells were treated with various dosages of nanoparticles and analyzed for cytotoxicity and uptake. The collected zeta potential of the synthesized nanoparticles was a very positive +39.8 mV which is advantageously positive for use in neuro-oncological applications because of their ability to effectively and safely traverse the blood-brain barrier. By observing nanoparticle uptake and cytotoxicity, I was able to collect significant results relating to the use of chitosan-coated nanoparticles for the treatment of

GBM via effective targeting of CD44. By comparing nanoparticle uptake in CD44-blocked cells and non-blocked cells both treated with chitosan-coated iron oxide nanoparticles, promising data was gathered that showed the viability of the CD44 targeting mechanism in chitosan-coated iron oxide nanoparticles because of the greater NP clustering in unblocked GBM6 cells.

Developing a Behavioral Phenotype Screening to Analyze Sex-Differential Risk in Autism

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Mentor: Mrs. Leya Joykutty

Autism Spectrum Disorder is the fastest growing neurodevelopmental disorder with four times the prevalence in males than females. Yet, there has been little focus on the differences in the manifestation and severity of autism symptoms across genders. Our study designed an objective metric to quantify behavioral differences in girls and boys diagnosed with autism. The current gold standard, Autism Diagnostic Observation Schedule (ADOS), suffers from the subjectiveness of clinician evaluations, inability to distinguish symptom severities, and failure to detect autism early because it only evaluates existing conditions of children. We evaluated 70+ autism symptoms not currently assessed in the ADOS through computer vision-based motion technology, automated speech analysis, and facial expression recognition to analyze sexual dimorphism in autism.

We hypothesized that boys with autism would exhibit more abnormal facial expression than girls, while girls would maintain statistically significant higher distance to adults than boys and have more deficits in vocalization. Using SPSS, we conducted t-tests with gender as the grouping variable to see how boys and girls differ in traits affected in autism.

We identified 10 quantitative indices of ASD symptoms where boys and girls differed in traits. The strongest gender-based divergence is in eye contact where girls make significantly higher eye contact. Quantifying traits like this can help improve diagnostics and ensure they reflect the reality of how girls and boys differentially experience autism. Overall, this study provides a foundation for automating autism diagnosis through digital phenotyping and identifies patterns of sexual dimorphism in autism.

Development of a Combinatory Filtration System for Pollution and Virus Abatement by Optimized Nanoparticle Deposition

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During the COVID-19 pandemic, face masks have become a critical part of the personal protective equipment for front-line workers and the public, resulting in an acute shortage of effective and affordable masks. Recent studies also indicate a strong correlation between ambient air pollution and COVID-19 cases. Air pollution from particulate matter less than 2.5 microns (PM2.5), is a significant contributor to cardiovascular and respiratory diseases. The goal of this study was to develop a mask with an optimized nanoparticle coating which has a dual capability of particulate matter and virus filtration, while being safe for human use. The nanoparticles were selected based on their filtration, virucidal, and non-toxic properties. Particle filtration efficiency (PFE), tested with PM2.5 from incense sticks measured by laser particle detectors, improved by ~60% with nanoparticle coatings on KN95 and surgical masks. Virus filtration efficiency, tested using nebulized NaCl particles as a virus surrogate, improved by 95% with coated masks. PFE for engineered masks, with dual-layer nanoparticle coatings, initially declined but was restored by recharging. The nanoparticle retention efficacy, improved by 70% with the dual-layer coating, was well within the permissible exposure limits per OSHA standards. An accelerated durability test demonstrated ~95% effectiveness maintained over 4 equivalent days of wear. This technology

has several applications such as in personal protective equipment for virus protection, and in air-conditioning and car cabin filters for pollution abatement. In conclusion, the chosen combination of nanoparticles provides an effective and safe solution for both particulate matter and viral particle filtration.

Implementation of Time-Frequency Analysis for Seizure Localization

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Epilepsy is generally diagnosed using electroencephalograms, or EEGs, which are tests that detect electrical activity in a person's brain and consist of measurements of a set of potential differences between pairs of scalp electrodes. Signals recorded from living neurological tissue are extremely noisy at all scales from individual ion channels through collections of one or more neurons up to scalp-recorded EEGs. The noise recorded in these EEGs causes uncertainty in the location of the seizure-onset zones. It is not uncommon for surgeries to take place where the incorrect section of the brain is completely removed from a patient, leaving them to still have seizures. The success of focal epilepsy surgery strongly depends on accurate identification of the seizure focus, and the noise found in EEG scans obstructs the identification of these zones. It is vital to find an alternative method of analyzing and modeling EEG data to improve the technique of epilepsy diagnosis before performing invasive brain surgeries. The goal of this phase of the project is to investigate whether absence seizures can be best understood by separating the stimulus from the system using cepstral analysis of publicly available absence seizure data. If overtone strength is more clearly modeled using cepstral analysis, it could be an essential discovery to absence seizure research. This method of analysis requires taking the logarithm of the spectrogram which turns multiplied signal components (which is typically how components mix) into additive components. If the cepstrum proves to provide a more accurate analysis of EEG data, this method can be helpful in developing an objective program that can detect active or upcoming absence seizures.

GEORGIA

Advanced Control of Small Launch Vehicle

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Teacher: Dr. Joanne Shaw, The Gwinett School of Mathematics, Science and Technology

Cubesats and attosatellites are small, lightweight satellites that allow researchers to conduct experiments and collect data from low earth orbit (LEO); however, the costs to launch these satellites oftentimes hold back research from being conducted as even the cheapest methods to send them—secondary payloads—can bring the costs higher than recreationally feasible and thus hold back research. To serve as a proof of concept for a launch vehicle that could launch small satellites into orbit, I developed a model rocket that uses advanced applications of control theory in order to maintain a desired orientation. Using a 9 degrees of freedom inertial measurement unit for gyroscope data, a Kalman filter to improve the accuracy of the sensor readings, and a PID controller, I developed a vehicle that is capable of responding to errors in orientation. As launch vehicles become smaller, which is necessary to decrease the costs of launching small satellites, external factors such as wind have an increasing impact on the vehicle. This project serves as a proof of concept that advanced control is possible for small scale vehicles, and could one day be applied to LEO launch vehicles.

Investigating the Quantum Behavior of Simple Pendulums through Revival Times

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Mentor: Professor Michael Chapman, Georgia Institute of Technology

This experiment was conducted to better understand coherent systems by analyzing the relationship between the "quantumness" of a simple pendulum and its revival time. The researcher hypothesized that an increase in the squared ratio of the pendulum's length to its deBroglie wavelength (a decrease in "quantumness") would lead to an increase in the pendulum's revival time. To test the hypothesis, a pendulum at the unstable equilibrium was evolved over time in Python. The pendulum had initial uncertainties in the angular position and velocity which were proportional to the squared ratio of length to deBroglie wavelength. The revival time was measured as the time taken for the pendulum to return to within 1% of its initial angular position (π rads). Pendulums with varying magnitudes of squared length ratios were tested.

A Novel Implementation of LiDAR Mesh Classification and Image Classifiers in Assistive Technology for the Visually Impaired

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Teacher: Jennifer Berry

Current assistive technologies for the 253 million visually impaired are unsuitable for numerous reasons: unaffordability, poor ergonomic design, and computational inefficiency. Oracle is an application that efficiently classifies obstacles and relays their relative proximity using auditory and haptic feedback. Oracle utilizes the LiDAR sensor on an iPhone 12 Pro to classify objects by using convolutional neural networks to identify depth shapes. To increase classification variety, Oracle employs supplemental image classifiers, capable of classifying objects that are too geometrically complex to be identified through LiDAR depth data. To relay pertinent audio-haptic feedback to the user, Oracle implements a sectioning algorithm, dividing the camera's view into 40 subsections, sending raycasts to the center of each section. Both the sectioning algorithm and a hierarchy algorithm calculate which object is most pertinent based on distance and obstacle type. Classification accuracy, distance accuracy, and navigational time were measured to test the device's efficacy. The models (LiDAR and Image ML) had a theoretical accuracy of 99% and empirical accuracy of 97.4% in their classifications. Additionally, Oracle had an average overall absolute error of only 3.09% in its measurement of distances and yielded an average navigational time that was 28.8% lower than the White Cane across 10 obstacle courses. Statistical tests display statistical significance between Oracle's navigational time when compared to that of a White Cane, confirming the alternative hypothesis. The device can be used for affordable, non-intrusive navigational assistance, replacing technologies such as electronic canes and furthering intelligent assistive technology research.

Development of a Targeted Drug Delivery System for the Treatment of Covid-19

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SARS-CoV-2 has triggered a public health outbreak across the world, resulting in almost 5 million deaths as of January 2022. The arrival of vaccines has provided temporary relief, but these vaccines target the spike protein, which is highly prone to mutation, making it impossible to develop a long term cure to the coronavirus. As such, there is an urgent need for site-specific inhibition of the virus in the respiratory tract, as well as targeting the internal proteins of the virus itself. Past literature has identified 3CLpro and PLpro as enzymes essential to replication of the virus, as they assemble almost the entirety of the viral genome; as such, inhibiting the activity of these enzymes can stymie the spread of the virus. This project proposes the use of inhaled drug delivery to inhibit Covid-19 by synthesizing a formulation that can travel directly to the lungs via inhalation. In order to

streamline synthesis, existing FDA-approved drugs were analyzed using computational docking software and in vitro assays for inhibitory activity against these two enzymes. High-performing drugs were then encapsulated in PLGA nanoparticles to synthesize a drug delivery system, which was tested and characterized in vitro. Furthermore, in an effort to improve this drug delivery system relative to other drug delivery systems, the use of enzyme nanomotors was explored as a way to increase the accuracy of delivery by using computational simulations that mimicked conditions in the human body to model the velocity and trajectory of the nanomotors.

GREATER WASHINGTON, D.C.

Silk Fibroin Microspheres: An Innovative Approach to Improve Drug Delivery to the Lungs for the Treatment of Neonatal Respiratory Disease Syndrome (NRDS)

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Mentor: Dr. Makarand Paranjape, Associate Professor of Physics, Georgetown University

Neonatal Respiratory Distress Syndrome (NRDS) is a breathing disorder that is the leading cause of death in premature infants. It occurs when an infant is unable to produce enough lung surfactant, causing insufficient oxygen exchange and lung collapse. The prevailing treatment for NRDS is delivering natural animal pulmonary surfactant to the lungs to affect oxygenation and lung compliance. Known as INtubation-SURfactant Extubation (INSURE), this procedure involves an unstandardized protocol and is often inefficient and ineffective due to its inability to maximize the delivery of lung surfactant to the alveoli. Emerging studies have suggested that a more effective approach to drug delivery is administration through microspheres, as aerosolized microspheres containing the drug can maximize the surface area of the lung that is exposed to the surfactant. Specifically, Silk Fibroin (SF) best facilitates microspheres drug delivery, as SF is biocompatible and requires little resources to fabricate. However, its applications are limited due to its inconsistent batch qualities and uncontrollable degradation rates. This study introduces a protocol for designing SF microspheres containing CUROSURF®, a popular pulmonary surfactant, through the simple yet effective process of phase separation between SF and Polyvinyl alcohol (PVA). The efficacy of this protocol was optimized by iterating the procedure based on characterizations of the resulting microspheres through scanning electron microscopy, dynamic light scattering, and light microscopy. This study offers insight into a new method of drug delivery for treating NRDS in infants that addresses the long-standing issues of lung surfactant delivery experienced in today's intensive care nurseries.

Robust Weight Initialization Using Graph Hypernetworks for Efficient Adversarial Training

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Deep learning achieves superhuman performance on a variety of image classification tasks, but it remains susceptible to adversarial examples: adding purposefully crafted, imperceptible noise to inputs severely damages a neural network classifier's accuracy. The lack of robustness against such perturbations is concerning given the widespread adoption of deep learning in increasingly high-risk applications with potential for human harm such as autonomous vehicles. The state-of-the-art adversarial defense is adversarial training, but it significantly increases computational cost compared to that of standard training. This work proposes to mitigate this problem through initialization of neural networks with parameters predicted by a graph hypernetwork (GHN) before adversarial training. Previous research has already demonstrated GHNs' ability to predict network weights that produce impressive accuracy on standard image classification tasks. These findings motivate the extension of GHNs to the more difficult task of adversarial training, where parameters that are robust to a variety of adversarial examples are predicted. To this end, a GHN was trained on the DeepNets-1M dataset of diverse neural network architectures, learning to predict weights that are robust against adversarial examples generated on the CIFAR10 image dataset. Experimental results show that initialization of neural networks with GHNs significantly reduces adversarial training time compared to that of conventional gradient

descent training. The adversarially optimized GHN additionally outperforms vanilla GHNs by as much as 28 percentage points in resultant robust accuracy. Through lessening the computational cost of obtaining adversarially robust models, this methodology contributes toward making robust AI more environmentally friendly and accessible.

De Novo Prediction of RNA-Protein Interactions for Discovery of Tissue-Specific Binding Sites

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Mentor: Eric Wang, University of Florida

In eukaryotes, RNA-binding proteins (RBPs) interact with RNA to control post-transcriptional processes, including alternative splicing, polyadenylation, stabilization, localization, and translational regulation. RBPs and RNAs are differentially expressed between tissues, influencing the transcriptome-wide RNA-protein interactions that occur within each tissue. Current experimental techniques to identify RBP binding sites in vivo, such as UV cross-linking immunoprecipitation and sequencing (CLIP-seq), are expensive, time-intensive, and difficult to perform reproducibly. Here, I introduce a de novo method to predict tissue-specific RBP binding profiles from an RNA sequence in silico. This approach simulates RNA-protein interactions using a probabilistic model that leverages binding affinities predicted from in vitro RNA Bind-n-Seq data and protein compositions measured by mass spectrometry. I apply this method to investigate the binding of 86 RBPs across 32 human tissues, outperforming existing computational methods. I show that the model recapitulates well-studied examples of tissue-specific binding, such as the brain-specific binding of protein NOVA1. In addition, using this approach, I identify NOVA1 as a potential critical protein in the progression of benign adult familial myoclonic epilepsy (BAFME), as NOVA1 binds the UUUCA repeat expansions present in the intronic region of SAMD12. Predictions from this model may aid researchers in understanding the functions of RBPs and uncovering their roles in understudied diseases.

Nanomaterial Design of Tungsten Disulfide for Near-Infrared-II Photothermal Cancer Therapy

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Mentor: Xuan Luo, National Graphene Research and Development Center

Photothermal therapy (PTT) is a new therapeutic cancer treatment strategy that offers advantages to traditional cancer treatments, such as minimal invasiveness, higher specificity, and precise temporal selectivity. Optical imaging in the second near-infrared region (NIR-II, 1000-1350nm) has prospective applications in PTT and is superior to the first near-infrared region (650-1000nm). However, it proves challenging to find NIR-II materials. To resolve this, multiple elements were tested in substitutional doping to tune the bandgap of monolayer Tungsten Disulfide (WS2). Two-dimensional materials have long proved to offer various properties, with WS2 predicted to have ideal adjustable optical properties. Quantum density functional theory calculations revealed the band structure and optical spectra of the different doped monolayer WS2. The bandgap of monolayer WS2 was successfully tailored to activate absorption in the NIR-II region. Results show that Zirconium doped WS2 had a bandgap of 0.04 eV and Titanium doped WS2 had a bandgap of 0.06 eV, which was ideal for NIR-II. Doping with Zirconium or Titanium exhibits strong absorption in the NIR-II range with absorption coefficients of 18830 and 13314 cm-1, respectively, which is very competitive for PTT. This demonstrates the potential of these materials as NIR-II photothermal agents. Novel materials were created which prove the viability of NIR-II PTT, a possible future cure for cancer.

Low-Cost Measurement of Water Quality Based on Scattering of Light

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Obtaining clean drinking water is challenging in rural areas of the least developing countries. While low-cost water filtering setups exist, there still lacks a simple but effective water quality monitoring method. Here, we demonstrated a simple optical method to measure the number of undissolved impurities in water. In this study, we compared four different water samples and observed that this method can effectively measure the invisible particles in water. Nonexperts can build and operate our low-cost measurement setup, allowing for convenient monitoring of physical water quality in poor rural regions and the wild. Furthermore, we proposed a design for a reliable, portable, and low-cost measurement device based on our experimental setup. This device can be quickly transferred onto assembly lines, significantly changing people's lives in rural regions.

HAWAII

Harnessing the Energy in Waves to Generate Electricity

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Having one of the highest sources of renewable energy densities, ocean waves are one of the most reliable ways to provide clean power. This research paper investigates a small-scale wave converter. With Faraday's law of induction in mind, the oscillating water levels can be used to move a magnet in and out of a coil without any manual labor being done. The device was deployed in a fabricated wave tank using basic construction tools. The variables tested were coil diameter, wave amplitude, the number of coil turns, and the number of magnets. It was found that out of three coil diameters of 14, 16, and 25 mm, the largest produced the most voltage and current of 10.6 mV and 6.1 mA. A higher wave amplitude was also discovered to increase the energy produced across 10 observations with different wave amplitudes in a linear trend. Building on the coil diameter experiments, the 25 mm coil was taken and the number of coil turns were increased in increments of 50. The averages were graphed to see a linear relationship with the 250-turn coil producing 61.3 mV and 43.6 mA. Taking the 25 mm coil diameter with 250 turns, the number of magnets were changed using magnetic disks connected in increments of 10. After graphing the averages, a linear relationship was found with the 40-magnet contraption producing 92.6 mV and 61.0 mA. These discoveries are analyzed in which improvements are suggested for future experiments.

Biomass Powered Desalination Year II: Combustion Tuning

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Each year, millions of tons of municipal solid waste are sent to landfills and a lack of drinkable water plagues populations globally. In order to address these increasing issues, this project began with a rudimentary idea of a biomass powered desalination device and the goal to create a functioning prototype that would use steam from desalinated salt water to generate electricity. Previous testing was conducted to find energy densities of biomass using calorimetry. In this year of the project, combustion tuning was focused on to develop a consistent and efficient combustion chamber to power the desalination process. A setup was developed to allow for efficiency calculations using heat transfer to a water source. The chamber was constructed mainly using terracotta pots and plates, computer case fans, and a power supply unit. Programmed combustion tuning was also explored, involving the automatic adjustment of fan speed and airflow based on combustion gas output. This project reviews test results of tuning using several different airflow rates. The data showed the approximate efficiency of the chamber and the anticipated airflow relationship with heat released by combustion. Limitations in available materials and current setup warrant further improvements in efficiency

using programmed combustion tuning. Thus, the test results will be used in further experimentation of the combustion chamber and prototyping the biomass powered desalination device with potential application in households.

Testing Fabric and Mask Particle Filtration Efficacy Against Durability, Distance, and BPM

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Since the rise of the SARS-CoV-2 pandemic, face masks have been widely accredited with decreasing the transmission of aerosol and respiratory droplets and slowing the spread of the virus. This has caused demand for surgical masks like the N95 to skyrocket and a plethora of homemade mask options to enter the marketplace. This project aims to test the efficacy of various masks/fabrics against coughing particulates, general wear, and aerobic activity to ultimately determine which masks/fabrics are the most effective at preventing the spread of SARS-CoV-2. All experiments used a 532nm wide-beam green laser and a negative-planoconcave, cylindrical lens, which highlighted droplets. In, Experiment 1, masks/fabrics were tested after frequent use for a year. Experiment 2 tested only surgical masks to differentiate between real vs. fake masks. Experiment 3 analyzed mask efficacy over long distances (6ft and 9ft). Finally, Experiment 4 used a heart rate monitor to test filtration efficacy of each mask/fabric as BPM increased. It was found that most face masks, excluding the neck gaiter, blocked and filtered more than 90% of particulates. Particle emissions were directly linked to higher BPMs, but most masks/fabrics maintained filtration efficacy. Additionally, nearly all masks were effective at both long distances and despite frequent use, and fake surgical masks performed slightly worse than real ones. Moreover, steri-wrap and kapa fabric were the most comparable to the N95, as a single layer of either fabric boasted a nearly identical filtration efficacy to an N95 in each of the four experiments.

Glue vs. Regular: Determining Which Cement Mix is Most Effective for Coral Restoration

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Mentor: Ms. Katie Nalesere
Teacher: Ms. Claire Bacus

Coral restoration has become a very prominent practice due to the decline of coral reefs worldwide. Coral restoration methods vary from asexual to sexual reproduction in either land-based or ocean-based sites. American Samoa - known for having generally 'good' reefs- has developed a territorial coral restoration plan to actively manage and encourage resilience within our local reefs. Restoration techniques are developed in a way to cater the natural shaping of individual reefs or revitalize certain sections within them. However, some of these methods have shown to be very time-consuming, tedious, and especially difficult without ideal weather and water conditions.

In American Samoa, the cement method is the most utilized restoration technique, especially when dealing with direct transplantation, due to its accessibility and affordability. However, it has shown to be very time-consuming, specifically when coming up with the right cement mix. Within this study, I will be addressing the washout issue faced when carrying out the cement method by conducting both land-based and ocean-based trials. I hypothesize that by adding glue to the cement mixture, it will not only reduce the amount of washout in the water but increase stability in the coral fragments as well. To test this hypothesis, I will be performing three tank-based tests: washout, fluidity, and dry-time; and one ocean-based trial: cement block method. The weight, measurements, and images of the cement mixtures will be used to differentiate the effectiveness of the two mixtures.

A Sustainable Alternative to Textile Dyes: Synthesizing and Applying PMMA Nanoparticles to Create Structural Coloration

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Mentor Ms. Jessica Lynn Saylors, ʻIolani School

Synthetic textile dyes have been one of the largest contributors to global pollution; uncontrolled discharge of textile dyeing wastewater negatively impacts public health and ecological balance. Toxic chemicals and metals in the wastewater are related to various cancers and skin problems and to lower levels of dissolved oxygen in bodies of water near textile factories. Structural coloration depends solely on the shape of an object, not any hazardous chemical components. The goal of this research is to sustainably colorize textiles by synthesizing and spray coating nanospheres onto fabrics. In this research, poly methyl methacrylate (PMMA) nanospheres were synthesized by stirring distilled water, methyl methacrylate, 2,2-Azobis(2-methylpropionamidine) dihydrochloride) initiator under an inert atmosphere. The method of preparing and spray coating the PMMA was optimized; after centrifugation, PMMA is prepared in a 100:1 ratio of PMMA/water solution and carbon black to spray coat onto fabric for 5 layers. The PMMA particles showed high durability on the fabric. By changing amounts of DW, MMA, and initiator, resulting colors included red-violet, violet, blue, turquoise, green, and yellow-green that can be created consistently. Applying practices and concepts learned from using PMMA, future research and ultimate goal consists of synthesizing and spray coating more sustainable nanospheres such as starch acetate nanospheres to apply onto textiles for structural coloration.

ILLINOIS–CHICAGO

Impact of Various Organic Substrates on Trametes versicolor Mycelium-Based Composites as a Basis for Novel Insulation

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Mentors: Dr. Catalin R. Picu, Dr. Han A. B. Wösten, Dr. Douglas B. Chrisey

With the rise of fossil fuel extraction and reliance on the non-renewable materials that are produced from these resources, interest in more sustainable materials has increased to combat the negative environmental consequences of our current economy. Mycelium-based composites, a material composed from the growth of fungal mycelium (the vegetative, fibrous component of mushroom-forming fungi) on an organic lignocellulosic material substrate (plant biomass composed of cellulose, hemicellulose, and lignin), make up a promising solution due to their potential to replace traditional insulators and packaging materials, many of which contribute to millions of metric tons of waste and pollution. Despite the benefits, the field is relatively new and largely undeveloped because of the complexities in the fabrication process. This experiment investigated the optimal substrate with which to compose the material. Focusing on comparing thermal conductivity measurements across different test groups (wheat straw, rice straw, hemp hurds) rather than comparing results with previous literature, which is often proprietary, the study concluded that rice straw composites were most promising and relatively comparable to traditional insulation as there was no statically significant difference between the groups (ANOVA $p=0.3235$). More research is recommended to continue to optimize the material, with focus on commercializing production.

The Effect of a Novel Biomedical Technique on the Reprocessing of Duodenoscopes Using Silver Nitrate and Methylene Blue Irradiated with Red Light

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Endoscopy-related infections are becoming increasingly prevalent, particularly in the era of multidrug-resistant bacteria. Duodenoscopes are the most difficult endoscopes to sterilize due to their small and intricate elevator component which is known to harbor bacteria that have the potential to grow biofilms, resulting in nosocomial infections. In addition, multidrug-resistant bacteria are becoming increasingly problematic in the medical field, as bacteria are developing resistance to bactericides at an unprecedented rate. This experiment modeled a duodenoscope contaminated with a biofilm from *P. fluorescens* (which modeled *P. aeruginosa*) and tested the bactericidal effect of a solution of silver nitrate and methylene blue when irradiated with red light. Once biofilms were formed on model duodenoscopes, the silver nitrate and methylene blue solution was applied and irradiated with red light. The models were then swabbed and absorbances were tested to compare the amounts of live bacteria. It was concluded that the treatment was a bactericide and effectively eliminated a significant amount of bacteria from the biofilms formed. All three experimental groups demonstrated this bactericide (ANOVA $p < 0.0001$), allowing for the rejection of the null hypothesis. To increase the validity of these findings, further research involving more real-world hospital conditions is needed.

How Complexity Affects Structural Stability: Using Protist Microcosms and Mathematical Modeling to Navigate Realism in Theoretical Ecology

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The nature of how ecosystem complexity affects stability has been long debated by theoretical ecologists. This broad concept, which encompasses how species richness, interactions, and community structure impact an ecosystem's ability to remain at or return to equilibrium, is in part challenging to research because of the practical inability to use large-scale experimental data in mathematical quantifications of complexity and stability. This experiment addresses this challenge using a recently developed method to model species abundances in all possible community compositions of four protists using data from a small set of experimental ecosystems. In addition, a novel method to quantify structural stability was proposed that uses the average magnitude of change in model parameters before species no longer coexist. The model accurately described the data ($R2 = 0.7$) and the results suggested that species richness, the measurement of complexity used in this experiment, is negatively correlated with structural stability with respect to change in both growth rates and interaction strengths. These results add to current research on the topic of complexity and stability and additionally show promise to be applied to larger communities. Further research is needed to confirm these conclusions due to the low number of species considered and large confidence intervals of species abundance.

Utilization of Ultrasonic Range Finder Sensor in Novel Robotic Systems for Haptic Feedback in Telepresence Surgery Application

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Robotic and telepresence surgery have resulted in numerous improvements to surgical procedures in recent years; however, loss of the sense of touch in such procedures remains a significant challenge. Existing research has addressed this challenge by exploring haptic feedback from force sensors for returning the sense of touch, but there is a lack of research surrounding the use of non-force sensors for haptic feedback. The purpose of this experiment was to investigate the effect of haptic feedback from ultrasonic range finder (URF) sensors—a type of non-force sensor—on the reduction of inaccuracy and imprecision of incisions. Participants created incisions with two robotic systems, one with and one without a URF sensor, and the inaccuracy and imprecision of the incisions were compared. Results showed inaccuracy (percent error) of incisions was reduced by more than half ($p=5.11785 \times 10^{-12}$), and imprecision (standard deviation of the percent errors) was reduced by almost half ($p=6.65082 \times 10^{-8}$). It was concluded that participants performed more accurately and precisely with haptic feedback from the URF sensor. Future collaboration with industry partners such as Intuitive Surgical will provide opportunity for implementation of URF sensors, which could impact surgeons and patients.

Pneumatic Extravascular Device for Variable Aortic Occlusion: Proof-of-Concept Design and Testing

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Mentors: Anthony E. Felder, Ph.D. and Miiri Kotche, Ph.D., Richard and Loan Hill Department of Biomedical Engineering at University of Illinois Chicago; Dr. Phillip Chung, M.D., Resident Physician at University of Washington; Amy Hofmockel, Oak Park and River Forest Library

Noncompressible torso hemorrhage (NCTH) refers to massive bleeding in the abdomen that cannot be treated via typical compression technology due to the placement of the injury. In minimally invasive surgery or triage care, intravascular devices such as the pREBOA-PRO are used to manage bleeds by partially occluding the aorta so that blood flow is restricted without inducing ischemic injury. However, in certain open surgeries—especially emergency or military operations, where imaging may be limited—NCTH may be better treated with an extravascular device that can provide comparable variable occlusion. This experiment designed and tested a novel prototype of a pneumatic, cuff-shaped device that could be wrapped around the aorta and inflated to various degrees to compress the vessel. The hypothesis was that a device of this nature could provide complete and partial occlusion on an aortic blood flow model. The device was iteratively developed using liquid injection molding with 3D printed molds and tested on a novel blood flow model using an ex vivo porcine aorta. A full prototype was unable to be developed, due to time and material limitations; thus, the hypothesis could not be fully supported or rejected. However, a modified procedure was used to test the proof-of-concept design, and, even in a limited stage of development, the prototype was able to reduce output by 10.2% (ANOVA $p<.0001$), demonstrating that this design shows promise for further prototyping.

ILLINOIS

Bayesian Modeling and Network Analysis of Longevity-Relevant Genes

Amy Dong

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Mentor: Dr. Gil Alterovitz, Brigham and Women's Hospital, Biomedical Cybernetics Laboratory Harvard Medical School

Improving human lifespans have always been an important goal for biomedical research. Many "longevity interventions", such as dietary restrictions and medications, have been shown to expand lifespan, and reduce the onset of aging-related diseases. However, the genetic factors that influence longevity are largely unknown. Though previous studies have linked the effects of longevity interventions to differential gene expression signatures, there currently lacks a computational method to accurately identify true longevity-relevant genes from the large pool of differentially expressed genes.

In this project, we developed a Bayesian method to identify potential longevity-relevant genes in a formal probabilistic framework, using a binomial distribution to model the number of times a gene is differentially expressed under multiple longevity interventions, and a beta distribution to model any prior knowledge that a gene is relevant to longevity. In addition, we performed a bipartite and unipartite network analysis to investigate the degree of similarity between different longevity interventions based on shared longevity-relevant genes. By applying our method to a large published mouse study consisting of gene expression data from 23 treatments, we computed the posterior probability distribution of each gene being longevity-relevant. Utilizing these posterior probabilities in our network analysis, we identified three main modules of interventions that affected similar genes, implying similar underlying molecular longevity mechanisms within each module.

Besides gene expression data, our method can be applied to other genomic datasets (e.g., identifying genetic mutations relevant to longevity), and used to investigate the genetic factors for other phenotypes of interest (e.g., cancers).

Synthesizing a 3D-Bioprinted Nerve Conduit Using Poly(L-lactide-co-glycolide) and Graphite

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Mentor: Dr. Caralynn Collens

Over 20 million people in the United States are currently living with peripheral nerve injuries, resulting in approximately $150 billion spent in annual healthcare dollars in the United States. The current gold standard surgical treatments for severe nerve injuries are primarily autologous grafts and secondarily collagen grafts. However, these two approaches have failed to be able to heal nerve injuries longer than 5 centimeters. To create a product that could potentially regenerate nerves over larger distances, a prototype of a 3D-printable conduit was designed with the materials poly(L-lactide-co-glycolide) and graphite, which were chosen based on literature review and interviews with experts. The materials were made into a bioink and 3D-printed. The prototype was then tested in the laboratory to determine its mechanical and microstructural properties. The high porosity of the printed product suggested that the nerve conduit would be conducive for cell attachment and growth. The average Young's modulus of the graft, 1.806 MPa, was comparable with other biomaterials that have been successfully implanted in the body. The high local conductivity of the conduit makes it especially suited for nerve regeneration because of the electrical impulses it can pass through to axons. Future directions would include animal and human testing for biocompatibility, degradation, and overall regeneration efficiency.

The Development of a Portable Ardunio-Based Water Quality Meter

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Sponsors: Kassie Henry and Terri Tobias, Southeastern High School

Due to increasing environmental degradation from agriculture and urbanization, there is a growing need for accessible water quality monitoring instrumentation. This is particularly true in developing countries who often lack proper infrastructure. In this paper, we present the development of a low cost, portable, and accurate water quality meter based on open-source hardware and software. The meter consists of a pH, conductivity, and turbidity sensors. The meter was compared to a Hach water quality meter. Both the pH and conductivity probes proved to be accurate and cost effective when tested. However, the turbidity sensor readings varied widely from the commercial meter and had a large margin of error. Using open-source hardware and software such as Ardunio can make analytical equipment such as water quality meters more cost effective and accessible to a wider range of consumers.

Identifying the Source of a Hydroxyl Outflow in a Region of High-Mass Star Formation

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Sponsors: Miss Kassie Henry, Mrs. Terri Tobias

High-mass stars (stars with masses above 8 times the mass of the Sun) generate great amounts of energy, more than several thousand times the energy generated by the Sun. At present, the mechanism that leads to the formation of these stars is unclear. Observations have shown that high-mass stars form in giant clouds of dust and gas, and while forming, can drive large scale outflows that push material outwards. A region of high-mass star formation in our Galaxy is G34.26+0.15, where evidence of an outflow was detected in a transition of the molecule hydroxyl (OH) based on low-angular resolution observations. Previous radio continuum observations also showed multiple ionized regions in G34.26+0.15, including cometary-shaped and compact ionized sources. The purpose of this project was to analyze high angular resolution observations of OH obtained with the Very Large Array (VLA) telescope to determine whether the outflow originates from the cometary-shaped ionized region or the more compact ionized sources. Specialized programs (VNC, PUTTY) were used to connect to a remote computer cluster in New Mexico. The Common Astronomy Software Applications (CASA) program was used in the remote cluster to obtain images and spectra from the VLA observations. It was hypothesized that the absorption detected in the G34.26+0.15 region would appear in front of the Southeast compact region of ionized gas. The raster image shows that the absorption was not tracing the Southeast compact region, but rather is located toward the cometary-shaped
region.

An Autonomous Drone with Object Detection and Tracking Capabilities

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Sponsor: Ms. Stacey Massie, Carbondale Community High School

This project develops an autonomous drone that can independently detect objects of interest and then fly closer to the object to take detailed photos. The drone hardware consists of a Holybro X500 drone development kit, a Nvidia Jetson Xavier NX GPU, and a RealSense camera. 3D printed fixtures were used to attach the GPU and camera to the drone frame. In software development, the Robot Operating System (ROS) was used, and three ROS nodes, ICODDA, pose estimation, and navigation control, were developed using Python. The ICODDA node performs image capture, object detection, and distance estimation. The YOLOv4 object detection network is integrated within the ICODDA node. A non-zero block average (NZBA) method was developed to estimate object distance in the presence of invalid and noisy depth data points. The pose estimation node implements a convolutional neural network that estimates the object's pose based on depth data. It achieves an accuracy of 92% when validated with a dataset collected in the project. Finally, the navigation control node uses three PID (Proportional-Integral-Derivative) controllers to constantly adjust the drone's speeds in the x, y, and z directions. It also implements a novel method to adjust the yaw speed based on recent pose estimation results. The drone's autonomous operations were successfully demonstrated in test flights with different objects of interest. It achieves 24.4 frames per second image processing throughput and 0.034 second control latency. The developed technologies can be applied to autonomous drones in surveying, inspection, and search and rescue applications.

INDIANA

Predicting The USD/CNY Exchange Rate: Models, Forecasts, and Novel Approaches

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A common goal for all stock investors and traders is to find accurate models they can confidently use to predict

future stock values/exchange rates in order to make profits. This project uses both conventional statistical methods such as autoregressive and moving-average models, as well as novel content analyses and probability distributions, to provide accurate forecasts for USD/CNY exchange rates in both quantitative and qualitative terms. Chosen using information gleaned from similar projects, the statistical techniques were coded into RStudio and run through different statistical packages. Accurate models were found after models of different types were evaluated. After analyzing their predictions, periods of significant deviation were identified. Through analyzing the key words in the captions of news articles written on U.S.-China economic relations in each of those periods, interesting conclusions on keyword correlations characteristic of these periods were identified. The Poisson distribution further cautions people against taking drastic actions by notifying them of the chances of a significant deviation occurring. Overall, the findings from this project have resulted in several models that are reliably accurate, with the most accurate being a short-term ARIMA(1, 2, 0) model having an average error of 1.45% and a long-term VAR(4) No Constant model having an average error of 1.37%. Additionally, included are some (to the author's knowledge) novel qualitative analyses of changes in the exchange rate. This project should also serve as a starting off point to be used to conduct further research into similar topics using comparable quantitative and qualitative methods.

Mechanical Properties of Crayfish Claws: Getting Inspiration from Nature

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Mentor: Nikhilesh Chawla, Ransburg Professor, School of Materials Engineering, Purdue University

We can study natural materials and the properties of these materials to obtain inspiration for new man-made material with outstanding properties. I studied the claws of a crayfish using a technique called nanoindentation. The Manus (the joint that connects the claw from the body), was tested for Hardness and Young's modulus. Hardness is the measure of how well a material can resist deformation, and Young's modulus is the measure of a material's stiffness. The results showed that the crayfish had a relatively low Young's Modulus of 5.4 GPa, and a good hardness of 0.26 GPa. The data was compared to Black Scorpion data that was collected last year through the same process of nanoindentation. The crayfish had about half the Modulus and the Hardness than that of the scorpion. I took images in the Scanning Electron Microscope (SEM) to analyze the structure of the crayfish. The crayfish has a layered structure of cuticle that provides flexibility and toughness in the material. It appears that the complicated layered structure gives a good combination of flexibility and hardness. The exciting part about this experiment is that the nanoindentation provides an understanding of how the crayfish has made their structure to help them in the environment using structural methods that have not been discovered before. Studying the structure of the crayfish can give us ideas for man-made materials. We can make man-made materials with the same structure the crayfish has to provide the same mechanical properties in the material that the crayfish has.

Life as a Quaranteen: An Investigation of the COVID-19 Pandemic's Impact on High School Extracurricular Participation and Friend-Making

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Extracurricular activities are a large part of the American high school experience, helping shape youth development and relationships. However, the COVID-19 pandemic has disrupted the lives of all American youth. This project aims to gather some insight into how extracurriculars and friendship have been affected by the COVID-19 pandemic. The investigation was conducted through a survey of students grades 9-12 at Bloomington High School South (n = 107). In addition to demographic questions, friendship quantity was measured using an altered Circle of Friends (Millen et al., 2019) and the modified version of the Inventory of

Parent and Peer Attachment (Raja et al., 1992) over two time periods, pre-pandemic (2019 - March 2020) and pandemic (April 2020 - Now).

From pre-pandemic to pandemic, extracurricular participation increased as seen in a rise in hours and number of activities students participated in. Especially, male students had a greater hike in extracurricular activities than females. Regarding friendships, friendship quantity remained the same between the two time periods, but friendship quality improved. Finally, students perceived that their needs for extracurriculars were less met during the pandemic, yet student satisfaction with activities remained unchanged. The pandemic had been difficult for students, but the results suggest the need to preserve extracurriculars for students in such times.

Understanding the Proteomic and Physiological Effects of Impella and ECMO Devices

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Heart failure occurs when the heart is unable to function efficiently—often caused by the development of an infarct, or an area of dead heart tissue. The extremity of infarct formation correlates with heart failure severity, and patients are often placed on ECMO/impella devices to assess the state of the patient for surgery. However, 50% of patients with these devices die due to complications that result from unknown causes. Additionally, there is no accessible way to predict infarct size and thus evaluate the severity of the disease. Research evaluating whether ecpella (bailout and preemptive) devices influence infarct size is needed. Furthermore, the hemodynamic effects of ecpella are poorly understood. As a result, the goals of this project are to identify biomarkers and signaling pathways involved in impella and ECMO implantation using a proteomic platform as well as use tools in machine learning to identify determinants of infarct size based on hemodynamic data and interpretability. More specifically, we used Ingenuity Pathway Analysis (IPA) to evaluate proteomic differences as well as pathways, diseases, and tox functionalities involved in post vs pre impella, post vs pre ECMO, and post impella vs post ECMO groups. Using hemodynamic reperfusion data of preemptive and bailout samples, K nearest neighbors, Xgboost, and regression models (linear, polynomial, lasso, and ridge) were used to predict infarct size. Five algorithms (the regression models and Xgboost) achieved low error rates as well as high R2 values in terms of predicting infarct size. Through interpretability and analyzing data distribution, it was found that the preemptive ecpella group provided better cardiovascular health compared to the bailout group. Thus, this research helps improve the understanding of the proteomic effects of ECMO and impella as well as the hemodynamic differences.

Identification of Pancreatic Cancer Driver Genes with Machine Learning

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With the lowest 5-year survival rate (9%) among all types of cancer, pancreatic cancer is considered one of the most lethal diseases in the world. Current conventional treatments often fail because there are no reliable genes to target in pancreatic cancer therapies and drugs. Hence, there is a crucial need for the discovery of new pancreatic cancer driver genes for the development of better treatments. This study develops a state-of-the-art machine learning workflow for identifying key driver genes for pancreatic cancer. Our workflow identifies several genes, including KRT17, S100A4, and PTGS2, which have high potential as targets for pancreatic cancer therapies and have been validated with over hundreds of publications in literature. Our workflow also identifies novel genes, including SSFA2 and NDUFA6, that have never been studied before while showing great potential as therapy targets. These new genes provide directions for further experimental studies for advancing pancreatic cancer treatments.

INTERMOUNTAIN

Oil Eating Microbes: Effects on Artemia and Oil Consumption in Saltwater

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Teacher: Linda Rost, Baker High School

Oil Eating Microbes (OEMs) are a type of bacteria that consume oil for energy. They are currently being investigated for use in bioremediation as a way to clean up oil spills, which are detrimental to marine environments. In this experiment the productivity of the OEMs in saline and freshwater environments in the presence of oil is analyzed, as well as their effects on the small marine invertebrates *Artemia spp.* otherwise known as brine shrimp. When any new organism is introduced to an environment, the effects must be carefully observed to avoid catastrophic results. The OEMs were found to not inhibit the hatching of brine shrimp, as the hatching rates were similar in the control environment. The OEMs grew most with the addition of oil with no salt; the salt inhibited the growth of the bacteria while grown in oil. However, these both grew more bacteria than the control with just water. When the shrimp was grown with the OEMs, the number of bacterial colonies decreased, which may indicate that the brine shrimp were eating the bacteria. The shrimp did not grow in the treatment with oil and no salt, and the number of bacterial colonies was much higher. Further research should be conducted to determine the effects of OEMs on larger aquatic organisms, as well as more on research OEM productivity using crude oil.

A Novel Experimental-Computational Approach for Advanced Solid Polymer Electrolyte Design

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Solid polymer electrolytes (SPEs) stand to revolutionize battery technology innovation by making batteries non-flammable, flexible, and more sustainable. However, SPE breakthroughs are limited by the highly time and resource-intensive nature of battery research. Even when suitable materials are discovered, optimizing the composition and experimental conditions presents another critical barrier to SPE realization. In this work, a data-driven approach to SPE development is presented. First, data is collected and analyzed from published literature, and then supplemented with independent experimentation to complete the SPE dataset. Then, six different models (linear regression, lasso regression, ridge regression, decision tree, random forest, and radial basis function support vector machine) were tested. The random forest model is identified as the most suitable model with the greatest predictive capability. It is then validated by independent experimentation and by comparing predicted activation energies to those reported in literature using raw predictions from the model. The random forest model is calculated to predict conductivity with a root-mean-square-error of 0.332 log(S/cm), which is on par with existing models in literature. By applying machine learning to incorporate important parameters of SPE synthesis, this study provides a foundation for accelerated SPE innovation and shows the potential for machine learning models to be used across all materials applications.

BI-lateral Lower Extremity Muscle Weakness as an Objective Measure to Assist in Determination of Athlete Readiness to Return to Sports Following Concussion

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Mentor: Bill S. Rosen, MD, PC

Residual muscle weakness can be a common objective finding following a concussion, or mild Traumatic Brain Injury (mTBI). Evaluation of this functioning may help determine when an athlete is ready to return to all their normal activities. The purpose of this study was to determine the incidence of bilateral hip musculature weakness in concussed student athletes and if this finding is common, could it be used as a quantitative test to determine an athlete's readiness for returning to full activity in their sport. If hip weakness is common in

concussions, monitoring this could become an effective way to determine whether or not an individual (or athlete) is back to their pre-concussion baseline. Awareness of this weakness and monitoring recovery would lower risks for secondary injuries. Participants completed a questionnaire detailing their concussion history and were evaluated using a visual screening assessment, two strength tests, and fine motor control tests designed to examine correlations between concussion and muscle weakness or motor neuron control difficulties. The results demonstrated that of the participants without previous concussion history in both contact and non-contact sport types, around 12% experienced weakness in one or both of the strength tests. Additionally, the results demonstrated that over 75% of individuals with concussion history experienced weakness in one of the strength tests. The application of this testing into concussion diagnostic testing, as well as developing a recovery protocol, has the potential to more quantitatively diagnose and accurately determine when an athlete is truly ready to return to sports following concussion.

Parent-of-Origin Differences in the Density of Trophoblast Giant Cells in Mouse Hybrid Crosses

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Mentors: Dr. Emily Moore, Dr. Kate Wilsterman, University of Montana at the Good Lab

Trophoblast giant cells are found in the placenta and initiate the invasion of the placenta into the uterine lining and provide important hormones for the regulation of the pregnancy. Genomic imprinting is a type of gene expression that, when two different species of mice mate, causes abnormal expression of certain traits depending on the parent-of-origin. We identified the number of trophoblast giant cells in each hybrid and pure cross of mice in their placentas and recorded the data. The results show a relationship between the maternal parent-of-origin and trophoblast giant cell densities. Furthermore, the mother of the cross is directly related to the density of trophoblast giant cells in the placenta. This study will help the scientific community understand more about the significance of trophoblast giant cells in the placenta.

Identification of Potential Inhibitors of Severe Acute Respiratory Syndrome Coronavirus 2 Envelope Protein Ion Channel Activity Using Machine Learning Techniques

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Mentor: Xikun Liu, Department of Chemistry & Biochemistry, University of California, Santa Barbara

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) is a viral disease that has caused a major global pandemic. There are many developing treatments for SARS-CoV2 including vaccines from Pfizer or Moderna but the field lacks specific treatments that target viral pathogenesis. Quick screening of drug candidates is critical to reducing the fatality rate and societal impacts of SARS-CoV2. We used 3 models including Random Forest, Support Vector Machine, and Multilayer Perceptron Neural Network to examine previously identified inhibitors. The most promising new inhibitors our classification models identified include: Methylene Blue Cation and Piretanide. Further study with Molecular Docking confirmed the effective inhibition of SARS-CoV2 Envelope protein by these 2 molecules. A set of chemical descriptors were proposed as key indicators for future screening using new datasets.

IOWA

Novel Mammalian Fibroblast Cell Culture Media Technique for Ultraviolet Cell Reduction

Jasmyn Hoeger
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Mentor: Cheryl Kluesner

Carcass bruising from horns costs the Canadian cattle industry $10 million a year (Anderson, 2012). It is vital to develop safe and cost effective advancements in dehorning procedures. Removal of horns raises the risk of

discomfort and pain to the animal; utilizing ultraviolet (UV) light as treatment can be effective when compared to current methods. The objective was to develop a novel media and technique to effectively culture horn producing cells for in vitro UV experimentation. Three media variations failed due to lack of cell reproduction and the presence of fungal or bacterial colonies. Horn producing cells demonstrated an average increase of 31.39% in a novel media mixture of 20 ml Ham's F12, 2% Amphotericin B from Streptomyces sp., and 1% penicillin. A UV prototype, developed in previous research was improved to guarantee isolated UV treatment of horn producing cells. Varying times were adapted for ultraviolet treatment. Horn producing cells were cultured in this media and evaluated by cell count using ImageJ analysis of digital images. Statistical analysis found significant relationships between cell death or reduction and run time of the UV lamp. As light run time increased, mitosis decreased. Ultraviolet light substantially reduced mitosis as compared to controls without UV exposure. Prototype design and implementation were effective for the isolated treatment of cells in novel media.

Efficacy of Antimicrobial Starch-Based Plastic Food Storage Films

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An estimated 1 in 6 Americans is exposed to foodborne illness annually. Previous research observed increased numbers of microbial contaminants present in plastic food packaging for fresh produce and eggs as compared to paper food packaging. In 2018, 14,530 US tons of plastic packaging were generated with 10,090 US tons ending up in landfills and only 1,980 tons recycled. This situation was exacerbated in 2020 as the Coronavirus pandemic impacted food storage methods and materials in an attempt to reduce possible transmission of disease agents through single-use and takeout containers. An increase of natural polymer-based film materials in the food packaging industry has occurred in recent years to help reduce petroleum-based plastic accumulation. The focus of this research was to develop and evaluate starch-based food packaging films while incorporating antimicrobial agents. Food compatible starch based plastic films were created and compared using propolis, elderberry, garlic, turmeric, and rosemary additives to analyze antimicrobial effectiveness. Fresh food products were wrapped in each film to observe food quality in addition to the number and type of microorganisms present during food storage. Bacterial *(E. coli)* and fungal *(Rhizopus stolonifer)* samples were added to each film and agar to observe microbial inhibition. Colonies were counted at pin tip and pinhead size and assessed with ImageJ. It was hypothesized that films incorporating additives would have less microbial growth than untreated plastic film and petroleum-based plastic film. Significantly less microbial occurrence was observed in starch-based and treated starch-based films compared to petroleum-based films.

Turbid or Not Turbid? That is the Question: Creating a Water Filtration and Sanitation Method for Developing Countries

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Clean and safe drinking water is essential for human life, but unfortunately, many people around the world don't have access to it. The slow sand filter is one method many people in developing countries use to obtain safer drinking water. The purpose of this project was to determine if the addition of another medium to the slow sand filter would significantly reduce turbidity and bacteria count. This project also studied if the addition of ultra-violet sanitation after filtration would result in significant bacteria reduction. Phase one studied the addition of activated carbon from coconut, corn husk, and activated carbon from orange peels to the slow sand filter. After filtration, the turbidity level (NTU) was observed. In phase two one sample from each filter was sanitized with UV light and one was left with filtration as the only treatment. The water was then grown in a petri dish, and the number of bacterial colonies was observed. In phase, one pea gravel and sand layers of the filter remained constant, and one filter tested had no additional medium. In phase two, the same amount of water was tested

per petri dish, and for each test, one petri dish had unsanitized water and one petri dish contained only agar. The hypotheses were that the activated carbon from coconut would have the lowest turbidity level and bacteria count. These hypotheses were supported by the data collected. After all three tests, the activated carbon from coconut had the lowest turbidity level and the least bacteria growth.

Biomechanical Analysis of Balance Beam Skills in Gymnastics

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Performing well on the balance beam holds great difficulty due to its small width and challenging skills that gymnasts complete. Even small shifts and changes in body positions can result in failure to keep balance and stay on the balance beam, which will cause significant score deductions and higher chances of injury for the gymnast. Gymnasts learn and perfect skills by verbal communication with their coach and extensive repetition of the skills over long periods. If coaches were able to make their suggestions based on quantitative data, rather than just observations, this would improve the efficiency of the skill development process.

The goal of this study is to find a quantitative correlation between gymnasts' body displacement and the performance on the balance beam.

It is hypothesized that the more the center of mass is displaced relative to the beam, the higher probability of gymnasts' failure is.

Videos of Junior Olympic gymnasts, Level 8-10, were taken while they performed the following skills on the beam: aerial, back tuck, and split half. For each skill gymnasts' body positions were analyzed from a snapshot when the first contact was made with the balance beam. Based on these snapshots the coordinates of the body's center of mass were calculated and compared with the central axis of a balance beam.

Results of this study supported the hypothesis and established the correlations between the body's center of mass and the success of skill execution on the balance beam.

Secret Sounds of Bees: Analysis of Honey Bee Vibroacoustics Using Hidden Markov Models

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Pollinators around the world are declining at a rate faster than ever recorded due to pesticides, diseases and pests, and habitat loss. Unfortunately, honey bee colony loss is difficult to prevent because early warning systems for colony health are lacking. I developed an early warning honey bee health detecting system that uses a machine learning model and vibroacoustic signals to provide information about the health of a colony before it is lost. Vibroacoustics are sounds and vibrations that are emitted by bees. I developed a Hidden Markov Model within MATLAB using a Hidden Markov Model Toolkit for MATLAB (MATLABHTK). Nine health states were included in the model, and 5-minute recordings were recorded at least weekly from 25 hives in Iowa from August-November, 2021 and processed through the model. The model was 100% accurate in identifying the signals from the training repository and 92% accurate when the entire collection of 258 recordings was assessed. This is the first reported model that provides beekeepers with a non-invasive analysis of their colonies' health that identifies vital situations like volatile chemical exposure, robbing, active honey flows, etc. This model can be used to reduce colony loss rates when combined with mitigation strategies from beekeepers.

JERSEY SHORE

Effects of Resveratrol on Myelination and Oxidative Stress in Leukoencephalopathy

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Leukoencephalopathy with Brainstem and Spinal Cord Involvement and Lactate Elevation (LBSL) affects the white matter of the central nervous system, and there are about 100 documented cases in history. LBSL is caused by a mutation in the DARS2 gene, which results in a chain effect of abnormal activities that lead to a myelin deficiency as well as oxidative stress in mitochondria. While there are therapy treatments that reduce the severity of LBSL, there is no cure. Resveratrol, a common supplement, could aid the mitochondria in energy production, meaning that it could potentially promote remyelination in LBSL. Resveratrol is also an antioxidant, so it could reduce the oxidative stress induced by LBSL. Two gene expression data sets were utilized: a gene expression model of LBSL and a gene expression model of myelination after treating cells with resveratrol. Analysis of these two datasets suggested resveratrol as a good candidate for treatment for LBSL. Interferon-gamma was also found to play a crucial role in modeling the effects of LBSL as well as treating LBSL with resveratrol. This model was then tested in-vitro, where Schwann cells (S42) were treated with Asp-AMS to induce demyelination and then treated with resveratrol to induce remyelination. When the myelin levels were tested, however, the results were the opposite of what was expected: resveratrol was actually shown to decrease the amount of myelin in the cells compared with the control, which would mean that it is actually not a good candidate for treating LBSL or other demyelinating diseases.

Inactivation of MS2 Bacteriophage for Water Disinfection via Microwave Irradiation

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Mentor: Dr. Wen Zhang

Human enteric pathogenic viruses present in wastewater, even at low concentrations, are responsible for many fatal waterborne diseases. The MS2 bacteriophage was used as a model pollutant due to its similar morphology, size, and structure to pathogenic viruses in drinking water systems. This project tested the ability of a microwave system involving a microwave-assisted reactive membrane coated with a BFO catalyst to serve as an effective virus filtration system. Microwave irradiation activates the catalytically reactive membrane enabling the formation of active species which are germicidal and inactivate waterborne viruses. Batch filtration experiments indicated that the MS2 inactivation efficiency was 100% with a short time (1-2 min) with the influent MS2 concentration of 7.5×10^{4} PFU $\cdot$ mL^{-1} at flow rates of 6 mL $\cdot$ min^{-1}. The results of MS2 inactivation with/without catalyst coating demonstrated the significant role of the catalyst in inactivating MS2 at 100% with periods of irradiation as low as 1 min. This microwave reactive technology will open new horizons for a quick and efficient disinfection and viral removal in wastewater and other broad environmental media such as air or aerosol.

ARIEL: Adversarial Neural Evolution for Unified Variant Forecasting and Proactive Therapeutic Design

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Teacher: Dr. Susan Arrigoni

This research presents ARIEL, a deep-learning method for predicting COVID-19 variants and designing therapeutics to neutralize them. ARIEL is the first framework to simultaneously address these related problems of variant prediction and drug design. It does so through an AI-driven, adversarial evolution process. The COVID-19 spike protein is continually mutated to increase its own infectiousness, while the “inhibitor” (a

protein that prevents infection) is continually mutated to decrease the virus' infectiousness. Specifically, a Transformer-graph neural network pipeline (called "Dual Refinement" herein) first yields a numerical summary of the variant's infectiousness given the corresponding inhibitor. Next, this output is used by two recurrent networks–trained via reinforcement learning–to design 1) a more infectious variant, and 2) a more effective inhibitor. This process is repeated continually until ARIEL produces a COVID-19 variant, plus an inhibitor tailored to neutralizing that variant. As assessed by the third-party benchmark SpikePro, 64 of 100 variants predicted by ARIEL are at least as infectious as the Delta variant. Similarly, as assessed by the third-party benchmark Rosetta, 84 of the corresponding 100 designed inhibitors are likely to bind to the virus, preventing infection. Furthermore, ARIEL was able to forecast Omicron's spike mutations prior to Omicron's November 2021 arrival. Not only does ARIEL predict (and rank) highly infectious variants and design reliable inhibitors, it does so several orders of magnitude faster than in-vitro methods. By predicting COVID-19 mutations and proactively designing therapeutic approaches to counteract them, ARIEL can help mitigate future variants even before they exist.

Schwann Cell Support as a Novel Approach to Peripheral Nervous System Demyelinating Disease

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Peripheral nervous system (PNS) degenerative diseases are characterized by nerve impulse conduction anomalies and neurodegeneration. Demyelination, a degenerative process that erodes away the myelin sheath which protects neurons, is often the underlying cause. Myelin production is orchestrated by Schwann Cells (SC), which wrap around nerve axons to produce myelin. However, current PNS disease treatment focuses on the neuron, not the SC, with the goal of immunosuppression. Additionally, PNS degenerative disease drugs can have severe adverse effects. This research aimed to treat demyelination in PNS degenerative diseases by targeting SCs non-invasively. This approach is based on studies demonstrating that patients with demyelinating diseases have decreased blood serum ascorbic acid levels. Therefore, this research examined the relationship between exogenous ascorbic acid application and the SC's potential to myelinate neuronal axons in PNS degenerative disease. Employing an *in vitro* SC-neuronal cell demyelination co-culture model, it was found that ascorbic acid application increases SC myelin production as a treatment (210%) and as prevention (222%), reduces SC oxidative stress, and increases ECM signaling and remodeling molecules. *In silico*, gene set enrichment and ontology analysis corroborated these *in vitro* findings, revealing a deeper understanding of mechanism. Furthermore, a regression model was developed from *in vitro* data predicting likelihood of developing a PNS degenerative disease (adjusted R^2 of 0.945) based on potential SC biomarkers which can be measured non-invasively. Overall, data suggests ascorbic acid as a potential neoadjuvant and adjunct treatment in PNS degenerative diseases and suggests mechanism in a novel approach of targeting the SC.

Improving Psychological Resilience to Acute Stress and Anxiety: A Non-Invasive Solution To Attain Sympathovagal Balance Using Novel Neuro-Cardiac Biomarkers

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Chronic stress and anxiety often cause mental and physical dysfunctions. Inevitable cardiac responses usually accompany as a part of the autonomic nervous system's reaction to combat stress. But frequent autonomic imbalances have been strongly implicated in the pathophysiology of depression, post-traumatic stress disorder (PTSD), and other mental illnesses. However, the central questions about stress and its connection to heart-brain mechanisms are poorly understood. Physical touch has long proven to improve HRV (heart rate variability)

by engaging our parasympathetic system to reduce stress by releasing serotonin, dopamine, and oxytocin. The current study investigates a non-invasive solution to quantify stress, attain autonomic nervous system balance, and improve cardiovascular health. Simultaneous electrocardiogram (ECG) and electroencephalogram (EEG) recordings were obtained from eighteen subjects while administering stress-inducing Stroop Color-Word Test (SCWT) and Paced Auditory Serial Addition Test (PASAT). A random forest supervised machine learning classification model is developed to quantify these recordings and strongly correlate brain fatigue and HRV. A low-cost wearable device is built to run the ML model to predict the incoming stress signals and generate preprogrammed vibrational waves (89Hz - 114Hz). These waves can induce a sense of soothing touch, which naturally engages the parasympathetic system lowering heart rate and improving HRV. Experimental results showed that the wearable device predicted the incoming stress signal at an average accuracy of 98.54% with an average inference time of 2.1s to restore HRV. This research provides evidence that we can non-invasively improve HRV and build strong resilience to stress and anxiety by attaining autonomic nervous system balance.

KANSAS-NEBRASKA-OKLAHOMA

The Protective Role of NKG2D in Type 1 Diabetes Autoimmunity

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Over 12 million Americans live with Type 1 Diabetes (T1D), a debilitating autoimmune disease marked by insulitis of the pancreas and the destruction of beta-islet cells by effector T cells (Teffs). The Markiewicz lab hypothesizes that expression of the immune receptor NKG2D is associated with an equilibrium between CD8+ regulatory T cells (Tregs) and Teffs, creating balanced immune responses. Through single-cell RNA sequencing, the Markiewicz lab has identified the CD8+ Treg subset that inhibits diabetes to cells expressing the following surface markers: CD44, CD62L, and Ly49A. While CD4+ Tregs have been the focus of a majority of studies on T1D autoimmunity, the mechanism of CD8+ Tregs remains undetermined. We suggest that the absence of NKG2D will limit the proliferation of the aforementioned subpopulation in the non-obese diabetic (NOD) mouse model; to test this hypothesis, we harvested spleens, pancreatic lymph nodes, and axillary lymph nodes from NOD NKG2D wild-type (WT) and knockout (KO) mice. We then performed CD8+CD62L+ cell enrichments and flow cytometry analysis on these tissues. Contrary to our hypothesis, the spleens and pancreatic lymph nodes of the KO mice contained a significantly larger population of CD8+CD44+CD62L+Ly49A+ T cells versus the WT mice, allowing us to conclude that NKG2D signaling does not enhance the proliferation of Ly49a+ Tregs in diabetes-associated tissues. These findings regarding NKG2D signaling and the proliferation of CD8+Ly49A+ Tregs will provide a greater background on NKG2D's protective role in T1D and thus could provide therapeutic targets for the treatment of the disease.

Surface Biofilm and Spectral Analyses of Eight Common Plastic Materials Exposed to Different Environmental Conditions Using Basic Spectrophotometry and Advanced Microscopy

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Microplastics are an environmental pollutant and an emerging threat. This experiment's purpose was to determine if it is possible to differentiate microplastics degraded in four distinct environments: water, soil, ultraviolet light exposed, and a control. This project proposes a method for microplastic polymer identification. The hypotheses suggest it is possible to differentiate degraded microplastic polymers by their absorbance of light and fluorescence emissions spectra. If successful, this technique will most certainly be useful in further investigations and experimentation dealing with identification and removal of microplastics from our environment. This experiment encompassed the analysis of eight distinct polymers, each exposed to four separate conditions. This experiment featured the use of advanced microscopies: fluorescence microscopy,

and scanning electron microscopy. These imaging techniques were utilized to further analyze the accumulation of biofilm on microplastic surfaces and the possible limitations it may cause on the validity and functionality of the proposed identification method. In addition to advanced microscopy basic spectrophotometry was also incorporated to test the efficacy of a simple spectrophotometer (SpectroVis), and its use in differentiating microplastic polymers by citizen scientists in the near future. SpectroVis graph data was collected and sorted into spreadsheets which were then interpreted using statistical analyses, ANOVA, and the T-Test. Results from T-Tests and ANOVA tests provided significant statistical support in declining the null. Therefore, based on statistical evidence and visual representation by imaging microscopies, the conclusion was made to reject the null hypotheses and support the validity of the hypotheses.

Analysis and Characterization of Styrofoam Consumption by Larval Black Soldier Flies, Hermetia illucens

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Mentor/Teacher: Dr. Kenneth Lee

Worldwide, thirty percent of landfill waste is composed of foam polystyrene, also known as Styrofoam. Despite the unsustainable demand for plastic all over the globe, there is currently no clear plan in sight to safely eliminate the single-use products that are overwhelming landfills. While intact, polystyrene foam products pose a threat to humans and animals as well as the atmosphere through the release of toxic pollutants into the air. In an attempt to combat the overarching waste problem, a variety of larval species including black soldier fly larvae have gained attention for their natural waste recycling abilities in regards to organic waste products like food waste and sewage contents, but recent experiments performed by the Shawnee Mission School District biotechnology program revealed black soldier fly larvae as a candidate for degradation of organic and inorganic material alike. The goal of this project thus far is to further analyze the ability of black soldier fly larvae to consume polystyrene and uncover how exactly the larvae survive on inorganic material. Currently, the hypothesis of these experiments suggest that the larval gut microbiome correlates directly with the digestive process. If so, a better understanding of these microbes in relation to polystyrene breakdown could mean a step in the right direction for the future of plastic pollution.

The Effect of Aftins on the Mitochondria

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Alzheimer's disease is a debilitating disease that causes memory loss in individuals. Aß accumulates in the brain of individuals with Alzheimer's, however, the reason for Aß being produced and the cause of Alzheimer's is unknown. There are numerous hypotheses for why Alzheimer's disease occurs. Two of these hypotheses are the amyloid cascade hypothesis and the mitochondrial cascade hypothesis. The amyloid cascade hypothesis states that the accumulation of Aß causes Alzheimer's while the mitochondrial cascade hypothesis states that mitochondrial dysfunction causes Alzheimer's disease. There are drugs that cause an increase in the production of Aß, aftins are one of these. These drugs are not always looked at from the perspective of the mitochondria and how the mitochondria affect the production of Aß. If aftins affect the mitochondria and cause an increase in Aß production, then further evidence for the mitochondria playing a role in the production of Aß will be acquired because a relationship between the mitochondria and Aß production will be shown. In an effort to look at aftins from the perspective of the mitochondria, SY5Y and iPSC-derived neurons were treated with aftins and the mitochondria were assessed in different ways. It was found that the mitochondria were affected and a relationship between the change in the mitochondria and the production of Aß was observed. This leads to the conclusion that the mitochondria do play a significant role in the production of Aß and could potentially be the cause of Alzheimer's disease.

Understanding the Role of Hyaluronan in Hepatic Aging

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Teacher: Dr. Kenneth Lee

We live in a world where the average human lifespan is increasing. With this increase comes age-associated functional decline of vital organs. Liver aging studies have begun focusing on hyaluronan, a molecule found in the extracellular matrix. Hyaluronan's long polysaccharide chain structure enables multiple necessary cellular functions such as cell communication, tissue injury recovery, and provides structural support for the cell. Hyaluronan is prone to fragmentation, which can drive inflammation and fibrosis, a process known as inflammaging, leading to a decrease in cellular function. Inflammaging occurs naturally, but to what extent hyaluronan influences this process remains unknown. The current hypothesis is that the presence of hyaluronan will protect the liver against aging-associated functional decline. In order to test this hypothesis various assays were performed, including triglyceride assays, H&E staining, and picrosirius red staining. We performed these assays on mice of different ages in the presence or absence of hyaluronan synthases (Has3). These experiments allow us to determine the role of hyaluronan in aging, both qualitatively and quantitatively. My recent experiments demonstrate that triglyceride levels increase with age in both the wild-type and Has3 knockout mice. Moreover, we found that the difference in triglyceride levels is actually greater in the Has3 knockout mice than in the wild-type mice. Since triglycerides make the liver more susceptible to injury, hyaluronan synthesized by Has3 may play an important role in limiting hepatic aging phenotypes, including inflammation and fibrosis.

KENTUCKY

COPD Detection Algorithm for Use with Stethoscopes

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Mentor: John Heironimus

COPD is the #3 global killer largely because of misdiagnosis rates in frontline medicine. The current gold-standard frontline diagnostic test is a questionnaire with a misdiagnosis rate of 65%, and misdiagnosis rates globally may be in excess of 90%; Failure to detect and treat patients early leads to poorer outcomes and higher healthcare costs.

The aim of this project was to develop an algorithm that enables digital stethoscopes to detect COPD reliably. Stethoscopes are noninvasive and already in common use in frontline medicine today.

232 clinical stethoscope recordings were used. The recordings included healthy patients, patients with COPD, and patients with a variety of respiratory diseases. Each recording was reduced to four physical metrics: maximal Lyapunov exponent, correlation dimension, turbulence intensity and sample entropy. The metrics were then fitted to binary disease classification using logistic regression. The algorithm was evaluated based on sensitivity, specificity, p-values, and area under the ROC. In addition, a smaller training sample was selected randomly, refitted and evaluated against a test set of about 20%.

The best result was achieved with 79 anterior site recordings. The algorithm was 94.9% sensitive and 95.0% specific; area under the ROC was 0.97. Using only these anterior recordings, a training set of 60 recordings was randomly selected and refitted to binary classification. The algorithm was then evaluated against remaining recordings; it was 77.8% sensitive and 88.9% specific.

It was concluded that an effective COPD diagnostic can be created from stethoscope data that could significantly improve early identification of the disease. The intended application was frontline medicine, but the algorithm also proved more accurate than spirometry which is reported to have an accuracy rate of only 67%.

Secure and Efficient Routing of Wireless Sensor Network Using Blockchain and Deep-Learning Based Algorithms

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Industrial IoT systems have boomed due to recent innovations in wireless communication and digital electronics. An Industrial IoT system consists of sensors/devices which connected with each other through a wireless network and collectively called a "Wireless Sensor Network". These sensors provide real-time data on a scale of seconds and have been used in applications ranging from agriculture to entertainment. This system communicates data quickly with the base station through networks of their sensors. However, the open, distributed, and dynamic characteristics of these networks make them vulnerable to various types of attacks, thus seriously affecting their security and effectiveness. In 2021 alone, there were 155.8 million individuals around the world being affected by this. These attacks can have disastrous consequences and thus, it is paramount to find a solution to improve the efficiency and safety of wireless sensor networks. This research proposes a blockchain and reinforcement learning-based system to improve the security and efficiency of these networks. This system can prevent almost all attacks on the WSN compared with current system which is only able to prevent 80% of attacks and this system on average 45% more efficient than current systems.

Susceptibility of Diabetics to Air Pollution: The Role of Activation of NLRP3 Inflammasome in Alveolar Macrophages Exposed to Ambient PM2.5 In A High Glucose Environment

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Epidemiological studies have shown that individuals with preexisting conditions, such as asthma, COPD, fatty liver disease, and diabetes mellitus (DM), are more susceptible to air pollution. However, the underlying mechanisms are still unclear. The effects of ambient fine particulate matter (PM2.5) on mouse alveolar macrophages MH-S and the involvement of IL-1β in the increased susceptibility of macrophages to PM2.5 in a high glucose environment were investigated. The results showed that exposure of alveolar macrophages to non-cytotoxic doses of PM2.5 led to up-regulation of proinflammatory cytokine IL-1β, activation of NLRP3 inflammasome, increased nuclear translocation of transcription factor NFkB, and ROS generation, which were enhanced when the cells were in a high glucose environment. Although PM2.5 exposure also caused TLR2 up-regulation, combined treatment of PM2.5 and high glucose had no enhanced effects on TLR2. These results suggest that enhanced production of proinflammatory cytokine IL-1β in alveolar macrophages exposed to PM2.5 with high glucose may be through activation of NLRP3 inflammasome due to PM2.5-induced oxidative stress and increased NFkB nuclear translocation. This study not only provides further understanding of the potential mechanisms underlying the susceptibility of individuals with DM to air pollution, but also sheds light on potential preventative measures; diabetes medications that could prevent or reduce IL-1β production such as pioglitazone and glyburide may offer considerable therapeutic promise in high PM-polluted areas. In addition, to reduce PM2.5-induced oxidative stress, daily supplement of antioxidants such as vitamins C and E and fresh vegetable and fruits may be recommended for individuals with DM.

Identifying the Transcription, Translation, and Functionality of Circular RNAs Using High-Throughput Sequencing Data

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Mentors: Dr. Juw Park and Dr. Jae Hwang, University of Louisville

Circular RNAs (circRNAs) have been a novel discovery in the past two decades. Formed by a different type of alternative splicing called back-splicing, circRNAs have been found to have functionality in developmental tissues, cancers, mRNA translation regulation, neurodegenerative diseases, and miRNAs sponges. Although

circRNAs have been detected using various tools, there has not been a method to holistically analyze circRNAs and their functionalities through detecting the transcription, translation, and miRNA binding sites. This project attempts to develop this method and find evidence for functionalities of specific, novel circRNAs. By using high-throughput RNA-seq and Ribo-seq dataset obtained from the cerebral cortex of mice in wild-type and mettl3 conditions, a thorough analysis was conducted to detect circRNAs. Here, 2081 circRNAs were detected with specific circRNAs having possible functionalities. By aligning Ribo-seq reads to a circRNA index, a multitude of reads that perfectly matched the back-splice junction were found, indicating possible translation of a circRNA involved in the metabolic system and turnover of fatty acids. Furthermore, analyzing the miRNA-binding sites of differentially expressed circRNAs, 170 impacted biological processes were found, with the highest-confidence processes involving functionalities in biological development and regulation. Currently, the entire procedure is being created as a pipeline to be completed in one run. Thus, circRNAs can be detected efficiently with any publicly available dataset in various tissues of different organisms. This research is pioneering the path towards more simplified, effective tools for scientists and researchers to use, revealing circRNAs' broad application in various molecular and therapeutic targets.

Developing a Compact Wearable for Mental Stress Detection by Studying the Effect of Stress on Electroencephalogram (EEG) and Electrocardiogram (ECG) Signals

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Human beings undergo stress, which is a necessary evil in everyday life. The physical stressors are temporary and can be controlled. Emotional stressors like family and work pressures are difficult to adapt to. Positive stress is short-term and provides opportunity for growth and evolution whereas negative stress is a chronic stress that leads to serious psychological and physical disorders and is difficult to detect. The objective of this project was to design and develop a compact, low cost wearable for the detection of mental stress. The EEG and ECG signals were measured in the time domain under two conditions, the rest and the stress state. The stress state was simulated by Stroop color word and mental arithmetic test. Five volunteers were recruited for the experiment. The MindFlex headset connected to Arduino measures the visual cortex electrical signals at different frequencies. The ECG sensor AD8232 was simultaneously connected to Arduino and the RR intervals were recorded. Both devices had electrodes attached to the subjects and signals were measured for twelve minutes each second. ANOVA testing was done to analyze the data and it clearly indicated that there exists a statistical difference between the mean EEG/ECG values and the rest/stress states. It was then found from the mean heart rate values that when the mean heart rate value for four minutes exceeds 90bpm corresponds to the stress state. A wearable device was designed to alert the user via mini vibration motors whenever the mean heart rate for preceding four minutes exceeds 90bpm.

LOUISIANA

Functional Analysis of Parameterized Torus Knots

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Torus knots are knots that lie on the surface of a torus. Torus knots have a wide variety of applications in quantum mechanics, molecular chemistry, and topology. In this paper, a comprehensive study of the geometric and topological properties of torus knots is presented with emphasis on functional analysis. The torus knots were first defined by standardized parametric equations. Using the Wolfram Mathematica software system, I created interactive plots of each knot and calculated their dynamic properties: the first and second derivatives, curvature, and torsion. I also developed a program within Mathematica to visualize the tangent, normal, and binormal unit vector (TNB) frame of a torus knot in conjunction with a plot of its curvature and torsion.

Connections to fractals and Lissajous curves were found, and further confirmation of the Fáry-Milnor theorem and fundamental theorem of space curves was established. Overall, the results of this project could be used in understanding the intrinsic properties of torus knots and applying their characteristics to analysis of dynamic systems.

Assessing and Exploring the Efficacy of Sea Plants to Help Mitigate the Impacts of Ocean Acidification

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Teacher: Teresa Burchette

In coastal waters, acidification is often exacerbated by anthropogenic carbon dioxide (CO2) and acid wastes produced during biological respiration. However, less is known about buffering processes that counter coastal acidification in eutrophic and consequently, hypoxic water bodies. There have been proposals to throw limestone or olivine into the water, or chemically absorb CO2, but the energy needed to mine and distribute such minerals, and the unpredictable shift in food webs, have made these ploys unappealing on a global scale. This project explored a more sound, eco-friendly strategy to ameliorate ocean acidification—aquatic vegetation. Here, carbonate chemistry and sample processing were used to demonstrate the occurrence of a pH-buffering mechanism resulting from calcium carbonate production from the plants. This investigation examined four types of sea plants, bull kelp, giant kelp, seaweed, and seagrass. The four most current acidic environments (8.1+pH, 8.0+pH, 7.8+pH, and 7.6+pH) were simulated. The plants were submerged and sealed for ninety days, and their chlorophyll concentrations as well as the amount of carbon and calcium carbonate in the water were measured every seven days. The results found significant carbon removal for all the plant types, with an average removal of 96.8% ± 0.62% for giant kelp, 94.6% ± 0.49% for bull kelp, 92.8% ± 0.38% for seaweed, and 93.1% ± 0.42% for seagrass. These findings offer a previously overlooked mechanism in which restoring aquatic vegetation will likely enhance their combined buffering capacity, potentially providing further resiliency in the face of coastal ocean acidification.

Identifying Promising Antiviral Drug Candidates Against SARS-CoV-2 Using Computational Drug Repurposing Methodology

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Mentor: Dr. Elahe Mahdavian, Ph.D.

Responsible for over 460 million infections and 6 million deaths as of March 2022, the COVID-19 pandemic has disrupted the livelihoods of people across the globe. Research and development have contributed to effective vaccines, widespread safety protocols have aided in mitigating the spread of the virus, and drug discovery has decreased mortality. However, the demand for effective COVID-19 treatments is still significant. In this study to identify promising drug candidates for COVID-19, we focused on inhibition of the viral main protease (nsp5), which is a key enzyme in the viral replication cycle. Using a computer-aided drug discovery approach, we repurposed Beclabuvir, an investigational drug used in the treatment of chronic Hepatitis C. As a seed compound in previous studies, Beclabuvir has been shown to have a high binding affinity with nsp5; however, a large molecular weight paired with low water solubility renders this compound inefficient as a drug. We created a compound library based on structural similarity with Beclabuvir and screened thirty analogs for drug likeness using the Swiss ADME tool. Analogs with promising ADMET properties were then virtually docked with the structural model of the nsp5 (PDB-ID 6lu7) protein to determine binding affinities. The results of this study revealed three analogs of Beclabuvir with comparably high binding affinities with nsp5, thereby providing evidence for three potentially effective drugs against SARS-CoV-2.

Modeling the Atmospheric Evolution of Exoplanets in the Habitable Zone of M-Dwarfs

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Mentors: Raissa Estrela, PhD, NASA JPL and Adriana Valio, PhD, CRAAM
Teacher: Kris Clements

The evolution of a planet's atmosphere depends strongly on the properties of its host star. When their host stars are younger, planets can experience stronger winds and XUV emission. This is particularly true for planets orbiting M-dwarfs due to their close proximity to the host star. To determine if these planets hold an atmosphere, it is necessary to quantify the impact from the stellar wind and XUV fluxes. Here, I determine atmospheric mass loss due to stellar wind and photoevaporation of 4 planets in close orbit and 34 in the HZ. The wind properties and EUV energy of the M-dwarf host stars were calculated through rotation period and X-ray flux scaling through the planet's lifetime. The mass loss rate was then computed as a function of time, and then accumulated until the planet's age to determine the total atmospheric mass loss of the planet's primordial H/He dominated atmosphere. I find that:

1. Stellar wind can only remove a small fraction of the H/He envelope of Earth-sized exoplanets in the HZ of early-type M dwarfs, therefore photoevaporation is essential for removing significant amounts of H/ He.
2. Planets orbiting at >0.2 AU cannot be stripped of a primordial envelope due to stellar wind or photoevaporation.
3. 11 planets in the study could have lost a primordial envelope.

My results will help contextualize the atmospheric data taken by the James Webb Space Telescope. Further, understanding atmospheres through these improved evolutionary models will greatly help guide the search for habitable exoplanets.

Incorporating an Articulating Facemask into a Multidirectional Self-Centering Linear Damping Football Helmet System

Rachel Pizzolato
ELearning Academy, Metairie, LA
Teacher: Cathy Boucvalt, John Curtis Christian School

The purpose is to determine the potential to reduce linear acceleration and tangential velocity during front and rear oblique impacts of a football helmet facemask.

Independent Variables: Non-articulating Facemask Design (Control); Articulating Facemask Design
Dependent Variables: Acceleration (m/sec^2); Tangential Velocity (m/sec)

A facemask was constructed using a novel 3D printed multidirectional self-centering damping system with four independent articulating attachment points that mimic the 4-wheel independent suspension system found in many modern automobiles; and biomimic the design of a woodpecker's beak and shock absorbing properties of its skull.

A t-test was used to determine the significance between group means. Articulating designs showed significant ($p < .01$) reductions in acceleration and tangential velocity vs. (Control) at all sensor positions. The articulating design significantly outperformed the non-articulating design with average %Δ in tangential velocity at the front of the headform of -8.34% (front oblique impacts), and -5.63% (rear oblique impacts), and at the back of the head form of -10.61% (front oblique impacts), and -18.84% (rear oblique impacts). This suggests the experimental design has potential to reduce incidences of concussions and cumulative effects of repetitive impacts - a leading cause of Chronic Traumatic Encephalopathy (CTE).

Further improvements include incorporating lightweight, high-tech materials such as graphene and magnesium

infused with ceramic silicon carbide nanoparticles into the facemask and damping design. The technology has far-reaching implications for automotive and motorcycle racing, construction, military, and aerospace applications, along with areas with limited space and where multi-directional damping is desired.

MARYLAND

A Novel Short Block Length Coding Method for Arbitrary Channels

Efe Eroz
Montgomery Blair High School, Silver Spring, MD
Teacher: Ms. Angelique Bosse, Montgomery Blair High School
Mentor: Professor Tolga Duman, Bilkent University

Forward error correction (FEC) is a vital part of digital communication systems, and it is especially important in aerospace communications, where transmit power resources may be scarce. Presently, there is still room for FEC improvement for transmissions over complex channels and for short block-lengths. For these cases, I developed an algorithm to incrementally improve the signal set. Specifically, to transmit k information bits in n channel uses, I started with a random set of 2^k codewords in n-dimensional hyperspace representing all possible k-bit messages. A codeword's n coordinates represent the n wave amplitudes used to transmit the associated message. n each iteration, the probability p_{ij} of the receiver confusing a transmission of codeword c_i with codeword c_j is obtained via simulation for all codeword pairs. Then, c_i is "pushed away" from c_j through hyperspace by a distance that increases with p_{ij}. The aggregate update of the codeword c_i, then, is the vector sum of all such "pushes" emanating from the other codewords Updating all the codewords similarly and conducting power normalization constitutes one iteration. Simulation testing demonstrated that this technique's performance matched that of the well-known (7, 4) Hamming codes over additive white Gaussian noise channels and exceeded Hamming code performance over Rayleigh fading channels, halving the required transmit power. In fact, the use of empirically-generated probabilities of error allows this approach to be applied for any complex channel for which optimal codes may not be known, especially for short block-length coding.

Breaking 'Click the Crosswalks' reCAPTCHA: A Technological and Economic Analysis

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Teacher: Ms. Angelique Bosse, Montgomery Blair High School

Millions of websites depend on Google's reCAPTCHA v2 security software for protection from high-scale digital attacks like credential stuffing and data mining. However, as reCAPTCHA v2, which is built upon image detection and segmentation tasks ("click the crosswalks"), has aged, computer vision technology has dramatically improved, threatening reCAPTCHA v2's security. I aimed to measure reCAPTCHA's security by building and testing a bot that bypasses reCAPTCHA cheaply and quickly. My bot used computer vision to answer reCAPTCHA's image tasks; specifically, I custom-trained a YOLOv5 model for detection and a Mask-RCNN model for segmentation. My aggressive active-learning system significantly improved the accuracy of both models. I achieved a 98.77% classification accuracy on reCAPTCHA v2's most difficult, distorted images, which previous literature has not achieved on easy, let alone difficult, tasks. I also manipulated reCAPTCHA's risk analysis system and user interface to bypass reCAPTCHA efficiently. The average time-per-solve of my bot was 35.8 seconds; its cost-per-solve was $24 per million solves. This bot is 85x less expensive than all human-based reCAPTCHA bypasses, and 25x less expensive than all automation-based reCAPTCHA bypasses sold on the market. I cannot compare this price to previous literature, since my research is the first to investigate "security-by-economics." reCAPTCHA provides security by imposing high costs on bots; thus, my $24 per million result suggests that reCAPTCHA v2 is insecure. I also make several suggestions to improve reCAPTCHA v2's security, including networking security improvements and suggestions to retire/introduce several types of image challenges.

Effects of an Urban Estuary on Blue Crabs and Blue Crab Diet

Meredith Nishiura
Baltimore Polytechnic Institute, Baltimore, MD
Mentor: Dr. Eric Schott, Institute of Marine and Environmental Technology

Increasing development and urbanization greatly affect ecosystem dynamics in marine estuaries, yet these effects have gone underexplored. The blue crab *Callinectes sapidus* is a keystone species in the Chesapeake Bay, an estuary facing increased urbanization. Comparing data on blue crab diet to existing data on the prey community of the urbanized area can allow for a comprehensive picture of the interaction between blue crabs and the larger ecosystem. Data on the biodiversity of the Baltimore Inner Harbor were previously collected from biodisks, small disks placed in the harbor and allowed to accumulate a community of organisms. The resulting biomass represents the prey available to blue crabs, with barnacles, dark false mussels, oyster flatworms and clam worms composing the majority of biomass. DNA metabarcoding was used to compare these results to the stomach contents of blue crabs caught in the harbor, which resulted in an overamplification of blue crab DNA and underrepresentation of prey species, demonstrating the need for a blocking primer to suppress predator DNA. Future work will utilize a designed blocking primer to amplify prey species. The data may inform future research into the ecosystem dynamics of urban areas and provide insight into these marginal yet increasingly common communities.

Representation and Deep Learning on Brain Surface Data for Transcranial Magnetic Stimulation

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Mentor: Dr. Lipeng Ning, Harvard Medical School
Sponsor: Research Science Institute, CEE-MIT

Photocatalytic water splitting is a promising renewable energy source as an alternative for limited fossil fuels. The effectiveness of the conversion from solar energy to hydrogen fuel relies primarily on the material. Previously, researchers studied different Transition Metal Dichalcogenides (TMDs) such as WS_2, and $PdSe_2$. These materials perform well in certain aspects such as strong adsorption stability and promising abilities for hydrogen evolution reaction (HER), however, their band gaps are still not ideal. In this paper, I studied a new TMD material WSe_2, which is currently used in heterostructure photocatalysts. To my knowledge, this is the first assessment of using transition metal doped WSe_2 as potential photocatalysts for photocatalytic water splitting. Using first principles calculations, I evaluated the band gaps and other photocatalytic abilities of pristine WSe_2 as well as Cr, Mo, Ta, and Re doped WSe_2. Compared to previously studied TMD materials, three of my newly studied materials (pristine, Mo doped, and Ta doped WSe_2) demonstrated more desirable band gaps, which are closer to being ideal (1.23eV); The band edge positions of my materials are also closer to the ideal reduction potential of H^+/H_2 and the oxidation potential of O_2/H_2O. Furthermore, Mo and Ta doped WSe_2 monolayers undergo an exothermic process, indicating stable monolayers. Of the three selected materials, pristine WSe_2 exhibits the strongest water adsorption abilities. My results substantiate pristine, Mo doped, and Cr doped WSe_2 as potential photocatalysts for water splitting

First Principles Investigation of Transition Metal Doped WSe2 Monolayer for Photocatalytic Water Splitting

Celine Wu
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Mentor: Xuan Luo, National Graphene Research and Development Center

Photocatalytic water splitting is a promising renewable energy source as an alternative for limited fossil fuels. The effectiveness of the conversion from solar energy to hydrogen fuel relies primarily on the material. Previously, researchers studied different Transition Metal Dichalcogenides (TMDs) such as WS2, and PdSe2. These materials perform well in certain aspects such as strong adsorption stability and promising abilities

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MICHIGAN SOUTHEASTERN

Designing and 3D Printing PLA Based Universal Charging Adapters for Use in Charging Electric Vehicles

Jonathan Bryant
Renaissance High School, Detroit, MI
Mentor: Mr. Keith Young

Electric vehicles are vehicles that run using batteries and electricity rather than gas. Due to the production of electric vehicles showing an increase for years to come I wanted to create a charging adapter for electric vehicles. The purpose of this adapter was so that people could use it for situations in which they need to charge their electric vehicle, but the only charging stations around are ones that are different from your brand of EV. The filaments I used were PLA (Polylactic Acid) and TPU (Thermoplastic Polyurethane). I began to conduct a series of drop tests on the prototypes to evaluate the impact force that each prototype could handle. I tested it from a constant height and used different outside surfaces as my variables. I tested it on grass, asphalt, and concrete which are surfaces that the adapter would most likely be used on. After conducting the tests, I found that the TPU adapter was able to absorb the drop impact well enough on each surface so that it was able to maintain its shape without any damage being acted on it. Overall, TPU is the filament I have found to work the best so far with my adapter and its variety of properties such as its elasticity and heat resistance help it become a useful filament for machine parts in general.

Geometric Consistency-Based Self-Supervised Neural Network: A Novel Deep Learning Framework for 3D Human Shape and Motion Reconstruction

Michelle Hua
Cranbrook Schools, Bloomfield Hills, MI
Mentor: Professor Zichun Zhong, Department of Computer Science, Wayne State University

3D human motion reconstruction from a monocular video is one of the most attractive yet challenging research fields. It has the potential to enable 3D broadcasting, advance virtual and augmented reality, conduct sport analysis, deliver telepresence, etc. Existing machine learning methods for 3D reconstruction require a large number of hard-to-obtain training pairs, e.g., human images/videos and their corresponding 3D human models, and often suffer from performance degradation in practice due to appearance variations between the training and testing data. Therefore, I propose a novel geometric consistency-based self-supervised neural network (GC-SSN) for 3D human shape and motion reconstruction from a monocular video. In GC-SSN, the representation of a moving human is modeled with a geometric representation based on joints and silhouettes extracted from each frame of the video, thus avoiding the instability of appearance-based representations and constraints. During training, the joints and silhouettes of the reconstructed 3D human model are automatically extracted, rendered, and fed back to the reconstruction network to form a complete cycle. By enforcing the reconstructed 3D human model to align consistently with the extracted joints and silhouettes constraints from the input and output geometric representations in both the forward and backward directions, the generator, consisting of a

feature encoder and a regressor, in GC-SSN can build the 3D human model with a high accuracy. The GC-SSN is self-supervised with automatically extracted joints and silhouettes without any manual annotations or ground truth 3D human shapes. It significantly improves the domain adaption and outperforms other state-of-the-art algorithms.

Vaginal Microbiota in Recurrent, Remission, and Refractory Patients Diagnosed with Bacterial Vaginosis

Mounika Katta
Northville High School, Northville, MI
Mentor, Dr. Robert Akins

Bacterial Vaginosis, or BV, is one of the most common vaginal infections in women. It affects about 30-60% of women worldwide. In most patients, it is caused by a shift from Lactobacillus to polymicrobial flora, but the actual cause of this shift is unknown. Our hypothesis is that the abundance of specific bacteria in BV patients will determine whether treatment with oral metronidazole will be effective. In this project, BV patients treated with metronidazole were divided into three outcome groups: refractory (no recovery), recurrent (transient recovery), and remission (long-term recovery). We collected vaginal samples before and after treatment, and sequenced bacteria to determine whether compositional changes were linked to clinical outcome. We used R, Mega, and Microbiomeanalyst to analyze and graph our data. The data did not show significant differences in pre-treatment samples that could predict clinical outcome. In contrast, at post-treatment, we found certain bacteria that were significantly associated with recurrent and remission patients versus refractory patients after treatment. Future analysis of this area and data is important because it would eventually lead to clinicians being able to offer specialized treatment for BV patients.

Sputum-Based mRNA-Targeting Probes in Lung Cancer - An Early Diagnostic Tool

Diya Ramesh
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Mentor: Mayur Ramesh, Henry Ford Health System

Lung cancer, the leading cause of cancer death, has no simple, non-invasive early detection tests. This project aims to create a multiplex sputum-based RNA probe through the targeting of the mRNAs for tumor marker genes. These genes are significantly overexpressed in the disease and present in sputum. First, the mRNA sequences of EGFR, KRAS, and ALK genes were recorded from UCSC Genome Browser. RNA secondary structures for the sequences were identified. Six fully/mostly open regions (with no base pairing) of 21 nucleotides in length were located per gene, and complementary sequences (to act as probes) were generated. Then, each probe was tested using the RNAhybrid tool in Linux against the targeted mRNA sequence and reconfirmed with the DuplexFold Web Server. The three probes for each gene with the most negative minimum free energy (MFE) values, meaning the highest hybridization efficacy with the target gene, were chosen. All probes were then tested in RNAhybrid against 3 lung-specific genes, AGER, CLDN18, and SFTPC (controls). The chosen probes interact more strongly with their targets than with control genes, with average percent changes in MFE from control genes to the target genes being 92.1%, 77.9%, and 69.5% for KRAS, EGFR, and ALK probes respectively. Probes were additionally tested to rule out dimerization, and 1 ALK probe was removed due to higher probability of self-hybridization. Future experimentation would include clinically testing the probes on sputum samples from patients with and without cancer and eventual creation of an off-the-shelf test.

Antecedent Drought in Mangrove Response and Recovery to Hurricane Irma

Sonnet Xu
Troy High School, Troy, MI
Mentor: David Lagomasino, East Carolina University

Mangroves are important forests that provide numerous ecosystem and economic services. Storms place

pressure on mangroves, and when compounded with disturbances such as drought, potentially decrease ecosystem resilience. However, little is currently known about the impact of drought on hurricane damage and associated post-storm recovery. Airborne LiDAR measurements, satellite imagery, modeled wind speeds, and drought data was used to perform high resolution mangrove mapping across the Caribbean and characterize coastline vegetation damage, revealing over 80,000 hectares of dieback within the over 1 million hectares of mangroves identified. Pixel-based time series modeling revealed drought caused previous overestimation of hurricane damage. We found that mangrove dieback in 2017 actually occurred in two waves, the first driven by drought and the second caused by storm. The initial, drought-driven dieback accounted for nearly 7% of all 2017 damage. The second, hurricane-driven dieback was more widespread and severe, causing higher levels of immediate and long-term damage, and affecting taller trees. Mangroves damaged in the second wave were on average 2.7 meters taller than mangroves damaged in the first wave. A mangrove drought history index is proposed that successfully captures hydrological vulnerability due to current and historical drought conditions. Drought is demonstrated to decrease resilience and lower recovery rates, prolonging recovery times. Although mangroves are known to be resilient to hurricanes, the results suggest the increasing frequency and intensity of drought spells within the Caribbean present an opportunity for cross-disturbance damage exacerbation, negatively implicating mangrove response.

MISSISSIPPI

Identifying Genetic Biomarkers for Essential Tremor Diagnosis

Nicholas Djedjos
Mississippi School for Mathematics and Science, Columbus, MS

Nearly seven million individuals in the U.S. have Essential Tremor (ET), making it one of the most common neurological disorders. Current ET research aligns it with a Purkinje cell disorder in the cerebellum, the motor control center of the brain. ET is associated with life-threatening neurological diseases such as Parkinson's and dementia, yet still remains understudied. This study uses the raw RNA-seq data from 55 post-mortem cerebellum samples to understand the genetic background of ET. The genetic data were used to develop machine learning models for prognosis and further identification of ET genetic biomarkers. Differential Gene Expression (DGE) identified 86 differentially expressed transcribed gene transcripts ($p < 0.001$, FDR < 0.25). The gene transcripts were then input into Gene Set Enrichment Analysis (GSEA) where five pathways were identified as dysregulated after comparisons with the Hallmark and KEGG gene sets: Fatty Acid Metabolism, Cholesterol Metabolism, Ribosome, Axonal Guidance, and Parkinson's Disease. The gene transcripts were also input in Random Forest and Logistic Regression models for further analyses. After filtering the 86 genes to 32 with Random Forest optimization, the classification model predicted ET and control accurately 85% of the time. Logistic Regression was utilized to analyze the 32 genes individually, and 8 genes had a higher accuracy than 80%: SFTPA2, NLRP14, PLCD1, SCRG1, ANKZF1, INPPFD, EVA1C, and BTN3A1Identifying the aforementioned biomarkers both advanced and corroborated with existing scientific literature and could be used to diagnose ET. The addition of machine learning models with higher statistical power and a larger dataset would strengthen the genetic findings.

Assessing Racial Determinants of Wellbeing

Raeed Kabir
The Mississippi School for Mathematics and Science, Columbus, MS
Mentor: Dr. Reshmaan Hussam, Harvard Business School, Cambridge, MA

This paper reveals numerous psychological mechanisms and correlations that are relevant in the sphere of race and wellbeing, and thus relevant to all people because of the inevitable effects that race has on one's life. I show that the valuation of race is asymmetric across racial groups and that this immediately has repercussions in the real world. I propose a theoretical market where race is an item of transaction, under which this asymmetry can be analyzed systematically. Within this framework, I rename this nuanced form of information asymmetry

to be experiential asymmetry and discuss a new type of market failure, one where the cost to wellbeing is not immediately financial but psychological. Mathematically, I suggest two mechanisms that will reduce the asymmetry in this racial market and prevent market failure. This paper establishes empathy as a strong variable that could reduce asymmetry and then demonstrates the strong correlation between empathy and responses to key national events like the George Floyd protests of 2020 and the January 6th Capitol protest. Finally, I note inconsistencies in my dataset with the long-standing idea of loss aversion. I suggest that there exists something inherently unique to being a person of color that correlates strongly with valuing a gain more than an equivalent loss.

Simple and Low-Cost Production of Magnetite/Graphene Nanocomposites in Activated Carbon Matrix for Heavy Metal Ions Adsorption

Jessica Yan

The Mississippi School for Mathematics and Science, Columbus, MS

It is challenging to produce economical magnetic graphene-based adsorbents on an industrial scale for heavy metal ions removal. Here, magnetite/graphene nanocomposite embedded in activated carbon matrix (magnetite/G-AC) was synthesized via in situ catalytic graphitization of iron-impregnated biochar to obtain graphene encapsulated iron nanoparticles (GEINs) embedded in biochar (BC) matrix, and followed by steam activation of GEINs-BC. Steam activation aimed to upgrade biochar to activated carbon with oxygen functional groups, crack encapsulated graphene shell to graphene nanosheets, and obtain magnetic Fe3O4 by oxidation of iron, thereby improving the adsorption capacity of magnetite/G-AC-800 (153.2 mg/g) four times higher than that of GEINs-BC. The parameters on the adsorption capacity were investigated using Pb(II) ions as a typical pollutant as a function of solution pH (3–7), contact time (5–300 min), initial Pb(II) concentration (50–400 mg/L), and adsorbent dosage (0.05–0.25 g). The fitted pseudo-second-order kinetic model and Langmuir model indicated that the main adsorption mechanism was chemical adsorption over monolayer. This research developed a low-cost magnetic adsorbent with the advantage of simple large-scale production and excellent adsorption capacity per unit cost for remediating wastewater.

MISSOURI

The Efficacy of Antimicrobial Cleaning Products and Their Impact on the Respiratory System

Jacob Arnold

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Teacher: Peggy Veatch, Eldon High School

Exposure to common household antimicrobial cleaning products may lead to an increased likelihood of developing respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD). Numerous studies have observed this. Exposure to cleaning products in early childhood may lead to the child being more susceptible to developing asthma. Individuals who work in the cleaning industry have shown higher risks of developing COPD. In today's pandemic stricken world, cleaning products are used much more frequently, leading to an increase in asthma cases. These products are designed to kill microorganisms. However, it is possible that they also harm other organisms. Solutions were made from seven cleansers at four concentrations. *Staphylococcus epidermidis* and *Escherichia coli k12* were exposed to cleansers and their zones of inhibition were measured to test the products' efficacy. *Drosophila melanogaster* were tested to observe the effects of these products on other organisms. Ten *Drosophila* were put into medium filled vials. The vials were closed off with a foam stopper that had one milliliter of solution in it to expose the *Drosophila* to the products while still intaking oxygen. The number of dead *Drosophila* and visible motile larva were recorded daily for thirteen days. The data showed that exposure to higher concentrations of cleansers led to larger zones of inhibition in gram-positive and gram-negative bacteria. It also showed that some products may have a slightly negative effect on the lifespan and reproduction of *Drosophila*.

Femoral Rotation and Effect on Medial Tibial Stress Syndrome

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Wentzville Holt High School, Wentzville, MO

Medial Tibial Stress Syndrome (MTSS), also known as “shin splints”, is a common lower leg abnormality that can be a debilitating injury in runners and athletes in select athletic populations. It is one of the most frequently diagnosed injuries, specifying one third of all running injuries. Although many specific pathological contributors of this condition have not been identified, it can be concluded that repeated stress to the fascia insertion area of the medial soleus is associated with MTSS. It is also known that greater internal/external femoral range of motion (ROM) is a contributor to MTSS, also being noted as a risk factor for several lower leg abnormalities such as internal/external tibial torsion, genu varum (bowleg), and genu valgum (knock knee). Due to excessive femoral ROM being a great risk factor for MTSS, the purpose of this study was to identify a potential correlation between a specific degree or degree range of femoral rotation and MTSS expression. 24 subjects were evaluated for femoral rotation and MTSS expression. In addition, the athlete’s age, height, and weight were recorded. Athletes were also asked to report if they experienced MTSS before, during, or after the time of screening, during their athletic season. It was found after statistical analysis that there was no correlation observed between femoral rotation and MTSS expression. This study can aid further research by narrowing down the field of known risk factors to MTSS development.

A Novel Approach to the Mitigation of Organophosphate Aerosols using an Electrospun Poly(Vinyl Alcohol)/ Cellulose Nanofibrous Filter

Isabell Owens
Camdenton High School, Camdenton, MO

Chlorpyrifos is a widely used organophosphate pesticide which is not only used in agriculture but also used in attractions like golf. Chlorpyrifos is an inhibitor of cholinesterase and acetylcholine which means the functions in both the peripheral nervous system and the central nervous system are interfered with negatively. The residual exposure of such pesticides through inhalation is especially damaging towards the nerves and hormonal organs of the near residents. At the moment there are only purification technologies for water exposure.

In this study, a variety of metal retained cellulose nanocrystals modified with polyvinyl alcohol were fabricated to determine the efficiency of aerosol CP removal using filters. The CNCs were acid-treated with hydrochloric acid to be prepared for metal retention of FeCl3, CoSO4, and CuCl, separately. The metal retained CNCs were sonicated with PVA to be electrospun in wire mesh as a fabricated filter. This filter was used in a PVC pipe system for the removal of CP. The collection paper was washed out with acetonitrile and the solution is measured using a UV-VIS spectrophotometer. Wavelength absorbance number from UV-VIS spectrophotometer displaying a positive correlation between absorbance and adsorbance of chlorpyrifos indicating that the greater the number from the spectrophotometer, the more efficient the filter, signifying the utilization of heavy metal-ion modified cellulose nanofibrous filters. Specifically, the cobalt filter was the most significant given the round total compared to those of copper and iron. However, the numbers given by the instrument are up to interpretation in the way of inverse proportions and the understanding of the most efficient filter in the reduction of exposure.

Discovering the Potential of LiDAR Field Detection to Improve Space Debris Recognition and Evasion

Connor Starkey
Camdenton High School, Camdenton, MO

Increasingly cluttered space conditions have long impacted the reliability and safety of manned and unmanned space vehicles. With increased focus on space travel in the commercial and industrial markets, the existing conditions in orbital range transcend the current capabilities of detection and evasion technology for space

vessels. Space debris has long been a grave concern for industrial and commercial spaceflight as there is no effective method of detecting and avoiding space debris of varying sizes. According to the Joint Publication of Space Operations by the Joint Chiefs of Staff, Space has become a naturally hazardous environment to maneuver and is becoming increasingly congested. Space assets face many natural and manmade threats with the primary threat to satellites being space debris. (Scott, 2020). This experiment strives to develop a method of real time debris detection and evasion for CubeSats. Another component to the experimentation strives to accomplish completely autonomous functioning independent of manned interaction and relays.... (will continue with results).

The Effect of Anthropogenic Noise on Bumblebee Foraging Patterns

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Bumblebee populations in Missouri and around the world have been dwindling. It is important to research these creatures as they are crucial to the ecosystem and can forage plants that other pollinators cannot. Noise pollution may be harming these insects. This project was conducted to see if there were positive or negative effects of anthropogenic noise on bumblebee foraging patterns. It was hypothesized that anthropogenic noise harms bumblebee foraging patterns, decreasing the amount of foraging or causing avoidance of high-noise areas. Bumblebees were allowed to forage in an arena with a grid of numbered artificial flowers that had PCR tubes of sugar water in them. Tests were conducted with different types of noises played while bumblebees were foraging. The amount of sugar water left in the tubes was measured, and the amount consumed was calculated. Results did not confirm nor deny the hypothesis and indicated that the noise played did not affect the foraging behavior of the bumblebees. Several technical issues could have impacted the lack of significance found in the data. However, graphical trends suggest bumblebees avoid high-noise areas. Ultimately, more research needs to be done on the effects of anthropogenic noise on bumblebees and the insect overall.

NEW ENGLAND NORTHERN

Presence, Abundance, and Characteristics of Green Crabs and Their Effects on Maine Intertidal Community Characteristics

Dorothy Barron
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Mentor: Nitisha Lankhorst
Teacher: Dr. Barbara Stewart

The intent of this study was to determine the characteristics and impacts green crabs have on Maine rocky intertidal communities. Since the 1960s, the Maine Department of Resources has tracked green crab populations and noticed population increases. The Change in tides creates distinct intertidal zones that are submerged in water and exposed to air for different lengths of time resulting in increased physical stress. Despite challenges and stressors facing organisms in the rocky intertidal, these habitats support a large diversity of life, including the invasive European green crab *(Carcinus maenas)*. This study involved six coastal locations where biodiversity was determined: Simpson's Index. Green crab populations were caught and observed, and water quality indicators, such as temperature, salinity, dissolved oxygen, and conductivity, were determined. Biodiversity tended to be higher, closer to the low tide line, determined by a correlation test (Sears Island Right r^2=0.37, Lamoine r^2=0.77, Sears Island Left r^2=0.06, Perry r^2=0.03, Hulls Cove r^2=0.54, Castine r^2=0.75). It was found that in rocky intertidal ecosystems biodiversity isn't significantly impacted by the abundance of green crabs (n=6, r^2=0.014). Random sampling of 195 green crabs found that 73.3% were males and 26.7% were females (X^2=42.4667, p-value= $7.19*10^{-11}$). There was no significant difference between the size of males and females (t=1.4187, df=142, p-value=0.1582). Green crabs are well adapted and are successfully reproducing in rocky intertidal environments. Color distributions are different at each site (X^2=261.2875, df=108, p-value=$1.015*10^{-14}$) Green crabs have invaded rocky intertidal environments: negatively impacting other organisms within those ecosystems.

Novel Detection Method for the Identification of Microplastics in the Sediment of the Penobscot River Watershed

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Teacher: Dr. Barbara Stewart

Microplastics are polluting beaches, rivers, lakes, and oceans across the world. Due to their size, it is difficult to identify them and determine the extent of their pollution. This study focuses on microplastic pollution in the Penobscot River Watershed in Maine. Sediment samples were collected from eight different shores along the watershed, and microplastics were separated using density separation, filtration, and Nile Red dye. An image-processing program was created to determine the percentage of microplastics in each sample based on the area of 110 mm filter paper. Traces of microplastics were found in all samples. Deer Isle, the southernmost site, had the highest traces of microplastics. Dolby Pond, a site on the upper West Branch of the Penobscot River, had the lowest traces. Using Arc-GIS, population and human activity were mapped and examined. Sites with high human activity had higher percentages of microplastics. This project shows the extent of microplastic pollution along the Penobscot River Watershed, and how population, development, and human activity impact the pollution. These methods could be replicated by citizen scientists studying microplastics in their local environment.

The Application of Clay Filtration Tablets in Remediating the Effects of Industrial Emissions in the Penjajawoc Stream in Maine

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New surface water data show continued impacts of industrial development along the Penjajawoc Stream in Bangor, Maine. The Penjajawoc Marsh and Stream provide valuable ecological resources, including flood control, filtration, and species habitats, to the Bangor area. Although slowed over recent years, the marsh area sees continued development pressures that could adversely affect vital habitats, as shown through an increase in conductivity levels after storm events. Additionally, new public testimony shows continued impacts of heavy metals in drinking water throughout the state of Maine. Prior research conducted shows that silver-nanoparticle tablets are effective in reducing the concentration of copper in water. This present study focuses on the effect of these tablets on conductivity levels in source water from the Penjajawoc Stream in order to see if the tablets would be successful in remediating heavy metals while also keeping the conductivity levels within the EPA recommended conductivity threshold. By first monitoring conductivity levels in the Penjajawoc Stream, results indicate an increase from the first site with a conductivity level of 116 µS/cm to the final site further downstream with a conductivity level of 318 µS/cm ($n=12$, $p< .001$). By spiking source water with controlled amounts of copper sulfate pentahydrate, the tablets were tested through the use of visible spectroscopy while conductivity levels were monitored. Preliminary results show that each of the tablets were successful in reducing the concentration of copper (80.16% average reduction, $n=4$) while keeping conductivity levels within the recommended threshold. Thus, this project provides the potential for a cost-effective way to remediate heavy metals in surface water without largely impacting conductivity.

A Non-Invasive Approach to the Treatment of Equine White Line Disease Using Poly-Wrap and Manuka Honey Topical

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White line disease (WLD) is a significant pathological condition that commonly affects horses, leading to hoof deformity, wall fissures, pedal osteitis and chronic lameness. Lameness causes the largest economic loss within the equine industry. The equine industry creates 1.4 million jobs annually and nationally has a total gross impact of $112.1 billion (11). Traditional treatments are invasive and compromise hoof structure. They rely on the use

of antibiotics and chemicals to control microbial growth. There is growing evidence that antibiotic resistance in humans is promoted by the overuse of antibiotics in the veterinary medicine and agricultural industry (1). The research goal of this study was to develop a strategy for treating WLD that does not require antibiotics, chemicals, or invasive procedures. Sensitivity experiments of mono-floral honeys revealed that Manuka honey may be a viable alternative to antibiotics. The treatment developed uses the application of a polyester wrap to the affected hoof capsule, and Manuka honey-based antimicrobial as a topical adjunct. Hoofprint analysis determined that polyester-wrap effectively redistributed weight off damaged hoof wall. Treatment using poly-wrap alone caused an average 57% decrease in fissure length over 15 weeks, while treatment using poly-wrap with Manuka adjunct showed an average 96% decrease, indicating that Manuka had a highly significant impact on healing fissures associated with WLD (P=0.32). Poly-wrap with Manuka adjunct offers an easy to use, inexpensive, alternative treatment for reversing the effects of chronic WLD.

Creating a Low Cost Non-Invasive Blood Glucose Monitoring and Automatic Insulin Injection System with an Artificial Neural Network and Raspberry Pi

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Diabetes mellitus is the ninth leading cause of death worldwide, affecting millions worldwide and likely more due to inefficient testing, and is growing worse every year. The system presented in this research could provide access to essential healthcare to millions worldwide at a low cost and with a non-invasive method. The main way to treat diabetes type I is with blood samples and insulin injections; however, this method is problematic, as current methods of detecting when insulin injections are required can be inaccurate, painful, expensive, wasteful, and intrusive. These methods are expensive, and are reserved for richer countries and individuals. The research goals of this study were to develop (a) a low-cost, non- invasive, and accurate glucometer, and (b) a fully automated insulin injection system. A Raspberry Pi, Pi Camera, laser diode, and servo motor were utilized. The camera and laser diode use laser spectroscopy to determine the concentration of an individual's blood glucose. Deep learning with logistic regression was used to calculate the estimated glucose level of an individual due to its effectiveness in estimating values based on an image. The effects of image count and image resolution on the accuracy of the neural network were investigated. An average accuracy of 90.06% (SD 6.64, n=10) was achieved using multiple high-quality images. The embedded system involves a non-invasive, pain-free, lightweight, and low-cost alternative to the current methods of glucose detection and insulin injection.

NEW ENGLAND SOUTHERN

Developing a Novel DLC-Based Thermo-Photo-Betavoltaic Device for Remote Extensible Energy Conversion and Storage

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This patent-pending project is a high-efficiency energy production, conversion, and storage device, capable of utilizing the low costs and superlative thermal, semiconductive, and electrical properties of diamond-like carbon (DLC). Various stacked DLC configurations were attempted, through physical development and simulation modeling. The thermo-photo-betavoltaic energy conversion and storage device would be compact, long-lasting, and energy-efficient, able to be used in various environments, including remote locations and extreme environments. It is necessary to produce a more extensible range of power output, with higher current densities, and operational capabilities at higher voltages, to serve the ever-increasing needs of data-intensive computing operations, especially those in remote conditions. High sp3/sp2 DLC is capable of superlative energy production using both heat and light, inherently possessing a wider bandgap potential (up to ~5eV). During use in field emission, applications have been shown to demonstrate superlative electron emission properties when

exposed to a forward-bias voltage. A novel design is being proposed, utilizing waste graphite nuclear rods with DLC coatings to maximize the potential for energy output, while reducing the global supply of nuclear waste. Additional related designs are also proposed, utilizing thermophotovoltaics (converting thermal energy and photons into electrical energy), and betavoltaics (which generates electricity through the constant emission of beta particles), to lessen the dependence on greenhouse gases. Various stacked DLC configurations, primarily based on P-N junction designs, were simulated, implemented, and tested, demonstrating a clear photoelectric and thermionic effect with up to ~100mV output tested, and a theoretical efficiency exceeding 25%, beyond today's photovoltaic.

Customized and Optimized Treatment of Extended-Spectrum-Beta-Lactamase Bacteria for Individual Patients

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Mentor: Dr. Yangxiaolu (Will) Cao

Antibiotic resistance renders antimicrobial drugs - which had hitherto rescued innumerable lives from fatal bacterial infections - futile. It is imperative to prevent further evolution of multi-drug tolerant bacteria in the most economical way possible. This paper discusses optimizing and customizing intravenous-drip therapies for patients infected with antibiotic-resistant bacteria, namely the Extended-Spectrum-Beta-Lactamase bacteria. Utilizing ordinary differential equations to model the system's dynamic, efficiencies of four types of IV-drip pulse function treatments and the time it takes for each treatment to suppress the pathogen population were evaluated. Results revealed that a trapezoid pulse function intravenous delivery of antibiotics is most favorable. Subsequently, its parameters were randomized to identify optimal ranges of antibiotic regimen. Thereupon, efficiency of each randomized treatment was evaluated using a score matrix assessing the dosing length, dosing interval, maximum rate of antibiotic infusion, net consumption of antibiotics, and total number of treatments. Through radar charts and box plots, it was discovered that for more severely infected patients with higher initial population and growth rate, it is important to decrease the time interval and increase the time of maximum infusion rate - vice versa for mild infections. More specifically, for severe infections with high Beta-Lactamase secretion rate, the time interval and period for different rates of infusion are also key values to manipulate. Under all conditions, there is a limit value to the maximum infusion rate of high-scoring treatments. Additionally, compared to initial bacteria population density, growth rate and Bla production rate play more important roles in impacting efficacy.

***In silico* Design of APOBEC3G Inhibitors Through Site-Specific Fluorination of a ssDNA Oligonucleotide**

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Advisor: Celia Schiffer, Ph.D., University of Massachusetts Chan Medical School

The human protein APOBEC3G (A3G) deaminates single-stranded DNA (ssDNA) by mutating deoxycytidine (DC) to deoxyuridine (DU). A3G dysregulation induces DNA damage resulting in cancer evolution and reduced sensitivity to genotoxic treatments, thereby conferring drug resistance. To improve prognosis of cancer infections, A3G inhibitors were designed using deoxy-zebularine (DZ), a DC analog which inhibits cytidine deamination, substituted in ssDNA from an A3G-CTD2 crystal structure. To improve binding affinity of the DZ-ssDNA oligonucleotide to A3G, 2'-deoxy-2'-fluoro-arabino nucleic acids (2'FANA) were placed in varying sites on the strand due to fluorine's high electronegativity and hydrophobicity: indicators of increased enthalpic interactions. 2'FANA oligonucleotides additionally experience high duplex stability through a C2'-endo DNA-like sugar pucker which stabilizes noncanonical nucleic acid structures. Molecular dynamics (MD), a computational method that simulates molecular systems over time, was applied to study protein-inhibitor interactions. Use of 2'FANA-DC in the -1' position decreased binding affinity based on hydrogen bond formation data. This trend was observed for all modifications made involving 2'FANA-DC at -1'. Dual modification of 2'FANA-DT at the -3'

site and 2'FANA-DA at the 1' site induced the largest increase in binding affinity compared to the unmodified control, based on hydrogen bond formation data. Increased enthalpic interactions with minimal structural impact indicate the inhibitor model with the dual -3' and 1' site modifications as a drug candidate for the treatment of drug resistance in cancer infections and a preventative therapeutic targeting cancer evolution. *In vitro* NMR deamination assays will be used in the future to test this inhibitor model.

Computational Drug Discovery for Alzheimer's Using Gene Expression Analysis and Network Pharmacology

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Instructor: Kevin Crowthers, Ph.D.

Alzheimer's disease (AD) is a neurodegenerative disease that is currently incurable. Symptoms of Alzheimer's include impairment of cognitive functions, such as memory and learning ability, that progressively worsen over time. The complex pathophysiology of Alzheimer's has resulted in a lack of effective drugs that inhibit the disease progression, and there is a demand for more effective drug discovery as the affected population continues to grow. Multi-targeting computational approaches may allow for more effectiveness of intervention by targeting multiple causal genes and their pathways, contrary to many existing approaches that have only targeted beta-amyloid, a well-known protein linked to Alzheimer's (AD), and failed. This study utilizes three microarray datasets from the Gene Expression Omnibus (GEO). Genes were ranked within each dataset based on $|logFC| > 1.5$, p-value <0.001, gene ontology processes, and pathway annotations from STRING. The alpha-synuclein gene (SNCA) was identified as the most statistically relevant gene based on these criteria, and pathway analysis in KEGG suggests that it plays a role in senile plaque formation in Alzheimer's. Gene2Drug was used in this study to target four highly correlated genes with SNCA – CALM1, TUBB3, SNAP25, and MAPT – and identify the top 10 inhibitors for Alzheimer's intervention. The identified inhibitors in this study were Fluvoxamine, Levobunolol, Arcaine, Sulfaquinoxaline, Cefuroxime, Chelidonine, Perhexiline, DL-thiorphan, Ramipril, and Diphemanil Metilsulfate. Future extensions of this project include analyses of drug efficacy and Blood-Brain-Barrier (BBB) permeability, to facilitate a higher chance of success in animal model trials, drug testing phases, and the finding of a possible cure.

The Effect of ZnO Nanoparticles on Arabidopsis Growth in Elevated CO_2

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The increasing greenhouse gas emissions causing climate change have been observed to deplete the nutrient content of crops, which can impact global malnutrition. Zinc is one of the plant micronutrients most threatened by elevated atmospheric carbon dioxide (CO_2). Zinc oxide (ZnO) nanoparticles were investigated as a potential means of biofortifying plants against the effects of climate change. ZnO nanoparticle treatments were hypothesized to increase plant biomass, a relative indicator of zinc content, although only to a certain point, as micronutrients can become harmful at higher concentrations. *Arabidopsis thaliana* plants were grown in ambient and elevated CO_2. Each trial contained 10 groups of 25 plants that were either soaked as seeds, or watered during growth, a novel technique, with a solution of ZnO nanoparticles at concentrations of 0.0 mg/L (control), 0.5 mg/L, 1.0 mg/L, 5.0 mg/L, or 10.0 mg/L. After three weeks, the dry biomass was measured. The 5.0 mg/L soaking treatment yielded the highest mean biomass in ambient and elevated CO_2 ($p = 0.001$ compared to control). 5.0 mg/L was also more effective than all watering treatments ($p = 0.001$). The data suggest that, for *A. thaliana*, soaking the seeds in the ZnO nanoparticle solutions before planting was a superior treatment to repeated watering with the solutions during growth. Effectively increasing biomass in ambient and elevated CO_2 conditions, ZnO nanoparticles may be a viable strategy to combat zinc loss and increase crop yield in climate change.

NEW JERSEY – RUTGERS

Breakthroughs in Honeybee Health: Continuous-Release Mist Diffusion of Thymol-Based Essential Oils, Part II - The Field Study

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Honey bee *(Apis mellifera)* pollination is responsible for approximately 80% of all cultivated crops. Unfortunately, reports suggest losses of 30-50% of all honey bee colonies in the US. The greatest contributor to the decline of honey bee health is the *Varroa* mite. Synthetic chemicals are used to control *Varroa*, but the mites are developing resistance. Essential oils (EOs) may be a viable alternative. EOs are cheaper, environmentally-friendly, pose fewer health risks to bees and consumers, and most importantly *Varroa* have not developed resistance to EOs. However, temperature and humidity affect the rate of evaporation and therefore the mites' exposure to EOs. Currently, all commercially available thymol-centered systems are gel-based and work only by direct contact with the mite. Following a laboratory investigation (Part I), this field study (Part II) examined the use of thymol-based EOs, dispersed via battery-operated mist diffusers, to provide miticide efficacy within beehives. Across all tested EOs, the highest miticide activity occurred in the first two weeks of treatment. Miticide efficacy was recorded as follows: thyme>oregano>rosemary>control (vegetable glycerin). The early elimination of mites is critical as it results in longer bee lifespan and higher colony survival after winter. Honey bee safety was found to be comparable to the control. Mist diffusers were also more cost-effective than commercially available thymol gel-based systems (US$3.20 versus US$15-$18 per application). Continuous-release mist diffusion of thymol-based essential oils may effectively, safely, and cost-effectively be incorporated as part of a natural miticide control plan to enhance the chances of honey bee colony survival.

Innovative Climate Change Emissions Reduction: The Cargo Ship Flettner Rotor Centrifugal Vortex Exhaust Scrubber

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Sponsor: Selina Simon, Bristol Myers Squibb

Our global cargo ships transport 90% of goods and release 4% of climate change emissions and particulate, causing 7.6 million childhood asthma cases and 150,000 premature deaths annually. A novel centrifugal vortex scrubber integrated into a Flettner rotor creates a hybrid wind and fossil fuel powered vessel that cleans exhaust while generating auxiliary wind propulsion. 3D CAD modeling, computational fluid dynamics, and prototyping were used for design iterations and testing. Flettner rotor performance was measured in a water test tank and wind tunnel and not diminished by the scrubber. The exhaust scrubber was simplified, replacing high-maintenance moving parts with a cyclonic separation-based design for cylindrical Flettner rotor geometry. Results were statistically significant. The scrubber removed 42% of particulate matter without high-maintenance fans or alkaline water mist. The Kutta–Joukowski force generated was significant, even in mild wind. This Flettner Vortex Scrubber shows promise as an economically attractive design to reduce marine heavy fuel oil engine emissions and fuel consumption. Combining Flettner rotors with an exhaust scrubber makes the investment more attractive for ship owners and operators, and can increase the rate of adoption of this important climate change and public health risk mitigation technology. The Flettner Vortex Scrubber enables a neopanamax ship to transport 53 more TEU containers, worth $185,000 on one trip from Shanghai to New York. If conservative estimates of Flettner rotor performance scale to the global cargo shipping fleet, it could mean a climate change impact equivalent to taking five million cars off the road.

Real-Time 3D Human Tracking and Pose Construction Using Millimeter-Wave Radar System

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Mentor: Sateesh Pokkunuri

Deviceless human recognition offers excellent potential for human-machine applications in healthcare and intelligent environments. Although current methods using WIFI Channel State Information (CSI) achieve promising results in controlled lab settings, real-world applications are still limited due to issues with model training and rapid environmental changes. Millimeter-Wave (mmWave) bands have gained interest as an indispensable tool for high precision localization, real-time domain independence, and high angular and spatial-temporal processing. This study explores the use of a portable mmWave device to construct human poses accurately in real-time. The system will identify the radar signal variation caused by the moving subject and analyze the 3D point cloud generated by each moving body part. A deep Graph Neural Network (GNN) takes the 3D point cloud structures in the spatial dimension, learns the spatial relations between each 3D point cloud, and predicts the human pose structure. Experimental results across subjects, environments, and locations demonstrated an average accuracy of 98.92% with a 3.3ms lag time and 2.23cm average error compared to a professional 3D Depth camera with advanced skeleton tracking SDK. These results validate using a device-free mmWave system for accurate human pose construction under complex domains and none-line-of-sight (NLoS) scenarios.

An Exploratory and Control Study of the Endolysosomal Pathway in Alzheimer's Disease

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Alzheimer's disease is the most prevalent neurodegenerative disease today with 44 million patients worldwide, according to the World Health Organization. A hallmark of the disease and one of the first pathologies seen is amyloid-beta plaque. The endolysosomal pathway is involved in the secretion of the plaque as it is responsible for protein trafficking in the cells, specifically from the surface to endosomes. This study focused on developing a methodology for targeting and labeling proteins in endosomal compartments through imaging of cell lines stained with antibodies, endosomal markers, and fluorophores to better understand the endolysosomal pathway. Results show through multiple colocalization analyses that protein targeting and labeling was successful. Mander's Coefficients derived from the analyses indicated that the selected methodology correctly tracked the synthetic protein to the endosomes and labeled it efficiently. The results of this work can be used to manipulate the endolysosomal pathway in order to observe how endolysosomal dysfunction plays a role in the pathology of Alzheimer's disease.

Using Endogenous MicroRNAs in Virus Diagnostics

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Mentors: Dr. Gabriele Grunig and Dr. Alesha Grant

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic poses a severe threat to global health, as evidenced by the ongoing global pandemic. Presently nasopharyngeal testing is the gold standard for data collection, which is an invasive process that acts as a deterrent for repeated testing. The objective of this study was to explore the feasibility of using endogenous microRNAs (miRNAs) as an alternate biomarker in the oropharyngeal region. miRNAs, non-coding, small RNAs, are responsible for the regulation of genes post-transcription through degradation and adjusting levels of proteins. Previous studies have shown that miRNAs play an integrated part of the host innate immune response for coronavirus, acting as the first line of immunity. In the present study, oropharyngeal swabs were used to detect and amplify endogenous miRNAs via RT-qPCR. The limit of detection (LOD) of spike-in miRNA Sp6 was determined to be 10^3 copies. The stability of salival

miRNAs was also examined by analyzing samples over various time points, from 0 to 72 hours (about 3 days), to determine the requirements of sample storage. Lastly, the primers 22-3p, 17-5p, Sp6, and Let-7g-5p were used to detect and analyze varying levels of miRNA across donors, displaying the different miRNAs and their quantities that can be identified from salival samples. Although further investigation is necessary to determine coronavirus-associated miRNAs, this study supports the feasibility of using miRNAs from oropharyngeal samples as biomarkers for coronavirus diagnosis.

NEW YORK – LONG ISLAND

Utilizing Short-Term Memory (LSTM) Machine Learning Algorithm to Create Soil Moisture Prediction Models and Improve Water Productivity in Southern California

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Due to changes in the climate and poor water management practices, water scarcity is rampant ("Water Scarcity," 2019). Climate change will further increase variability in rainfall, with more dry spells, droughts, and floods, increasing the threat of a lack of fresh water and limiting available natural resources (Rockstorm et al., 2007). Most current agricultural systems use outdated irrigation methods and overuse water, demonstrating a lack of automated and efficient irrigation scheduling (Aguilar et al., 2015). Mass water wastage significantly reduces crop yields, severely impacting the world food supply. This project created an irrigation scheduling model using Long Short-Term Memory networks to accurately predict soil moisture using various environmental factors. Python code was written in Jupyter Notebook using the Tensorflow Deep Learning library. Through testing hyperparameters (batch size, epoch), the model was optimized, ensuring accurate and robust predictions which were validated through a comparison of actual vs. predicted values in a t-test, where a p-value of 0.47 was obtained, demonstrating there was no significant difference (actual and predicted values were statistically similar). Subsequent statistical tests resulted in a low mean square error (0.213) and a high r^2 value (0.852), demonstrating model accuracy. In conclusion, LSTM algorithms were able to create an accurate soil moisture prediction model for Southern California's agricultural output. Such prediction models will be useful in water conservation, helping improve the water productivity and water use efficiency in a given system, and being cost-effective and efficient in creating a decision support system for irrigation scheduling.

How Dietary Restriction Affects the Athleticism, Metabolic Rate, and Lifespan of Drosophilia melanogaster

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Mentor: David Gilmour, Professor of Molecular and Cell Biology, Pennsylvania State University

Obesity is a notable health risk factor that increases morbidity and mortality. Some factors that contribute to obesity are lifestyle choices including excessive eating habits, low exercise routines, and genetic factors. Although it is perceived that persons at an unhealthy weight have increased the risk of many metabolic disorders, it does not confirm that they will develop obesity-related illnesses. Dietary restriction (DR) is the limiting of total food intake without causing malnutrition. A common dietary restriction with strong benefits against obesity is a low-protein, high carbohydrate diet, which has gained popularity due to its ability to slow obesity symptoms in a timeframe of 48 hours as shown in studies with *Drosophila melanogaster*. Past studies have shown that fly strains, such as bmm^1, and DR can increase the lifespan of obese fruit flies. This study is the first to test the idea by comparing a normal diet with DR of male and female bmm^1 and *chico* virgin flies in a series of geotaxis, respirometry, and lifespan assays. Results showed that DR increases lifespan but not metabolic rate and athleticism. It also showed that bmm^1 flies had lesser symptoms compared to *chico*. No statistical difference was seen between males and females. By investigating potential beneficial dieting techniques, obesity conditions can be improved leading to better treatment options for individuals to live healthier lives.

A Novel Evaluation of Current Psychiatric Treatment Paradigms Involving Polypharmacy via Resting-State Functional Magnetic Resonance Imaging (fMRI) in a Sample of Patients with Bipolar I Disorder

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Bipolar I disorder (BD-I) is characterized by cycling between a manic or mixed episode, followed by a depressive episode. The DSM-V specifies criteria for forming a diagnosis, and psychiatric treatment is often decided by this diagnosis. Polypharmacy is commonplace for psychiatric treatment of BD-I, often combining several medication classes. With extremely high rates of inadequate treatment in BD-I, it's apparent that despite the availability of medications and techniques like polypharmacy, there's a lack of neuroscientific evidence to support the current treatment paradigm. Thirty-two BD-I patients were separated into two groups by the polypharmacy they were receiving: a second-generation antipsychotic (SGA) with a mood stabilizer, or an SGA with an anxiolytic benzodiazepine. The former is known to influence neurological glutamate levels, and the latter to influence GABA levels. The present study compared resting-state BOLD fMRI signals in the ventral striatum, a region along the glutamate pathway, and hippocampus, a region along the GABA pathway, between the two groups. These regions were chosen by combining knowledge of known neurotransmitter pathways and neurotransmitters known to be affected by the given polypharmacies. Data analysis revealed no significant difference in BOLD activation between groups in the ventral striatum or hippocampus. These results highlight current limitations of polypharmacy and suggest that the current level of integration among psychology, psychiatry, and biology is unable to provide a method for individually-optimized psychiatric treatment that'll adequately foster rapid and complete resolution of symptoms associated with mental illnesses. Evidence-based neuroscience must have a larger role in selection of psychiatric treatments.

Building and Coding a Non-Invasive Ventilator Using the Arduino Platform to Improve the Clinical Efficacy of Non-Invasive Ventilation Systems by Remotely Controlling the Respiratory Status of COVID-19 Patients

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The purpose of this experiment was to build, code, and test a non-invasive ventilator that could be monitored and controlled from a remote location via a mobile device. During this pandemic, people were being admitted into the hospital suffering from acute respiratory distress syndrome. To ease respiratory strain in these patients, they were connected to non-invasive ventilators (NIVs). Healthcare providers had to enter these patients' rooms frequently in order to control the pressures on the NIV, risking exposure to the virus. Having a NIV that could be remotely controllable via a mobile device from outside the patient's room is critical to mitigating the spread of COVID-19. The total production cost of this NIV was $230 and was coded using the Arduino programming language. Regarding the initial testing portion of the prototype, a testing lung used in my home was connected to the NIV in either CPAP or BiPAP and remote mode. I controlled the pressures on my device using the Arduino IoT app. When changes were made on the device, the NIV adjusted itself accordingly without physical contact. The clinician can also see the patient's oxygen saturation on their mobile device to better monitor their progression. The final stage tested the functionality of the NIV at NYU Langone Medical Center apart from its remote capabilities. All tests performed in CPAP and BiPAP modes had percent errors below the 15% maximum accepted in clinical practice, thereby supporting the efficacy of this prototype as a potential alternative for current NIV technologies.

Creating a "Third Eye" for the Visually Impaired with Object Classification

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With 285 million visually impaired individuals in the world, it is important for there to be technological innovations aimed at making their everyday lives easier and safer. After spending time volunteering at the Helen Keller National Center and analyzing injury trends, it was determined that, due to the prevalence of the white cane, people who are blind are most vulnerable in their head and neck region. To combat this issue, an object detection system was developed compatible with a hat or headband. In order to create such a device, an Arduino Uno R3 was utilized along with the Arduino IDE coding system. An ultrasonic sensor, buzzer, vibration motor, button, and battery were all connected to the Uno using wires, some of which had to be soldered to utilize the limited space available. Code was then developed that creates bursts of feedback (either sound or vibrations), with set break intervals depending on the distance from the object. For example, an object 150cm away will beep or vibrate once every 5 seconds while an object 50cm away will repeat every 1.4 seconds. Then the button was programmed to allow a user to toggle between vibrational feedback and sound, depending on whether the user is blind, deafblind, or in a social situation that would be more appropriate to use one or the other. Afterwards, it was found that these capabilities could be taken further, allowing a user to be informed on the types of objects in their surroundings, rather than solely the distance. Using Google Colab, a machine learning environment was created catered towards object classification. 24 everyday objects were taken out of the CIFAR-100 dataset. Then utilizing VGG-16, a type of convolutional neural network, a model was trained to recognize these 24 objects. After obtaining a training accuracy of 98% and a testing accuracy near 70%, the model was exported to XCode, allowing it to be run on a mobile device's camera. Finally, the model was successfully tested in real-world environments, placing all 24 objects in the camera's view and printing its predictions every second. With text-to-speech, these object recognitions are told to a visually impaired individual, allowing them to make decisions based on the specifics of their surroundings. They would now know to avoid walking into a table or car, and conversely, would know that they are able to sit on a chair or couch. With object classification, the possibilities for future technology in the blind community are endless. 24 specific objects can be expanded to thousands, giving the visually impaired a complete understanding of the world around them.

NEW YORK – METRO

Holographic Tomography of Fractal Aggregates

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Mentor: Professor David Grier, New York University

Holographic Video Microscopy (HVM) is an imaging technique which shines a laser on an object, capturing the shadow created. HVM analysis, which extracts the 3d position of an object, its radius, and its refractive index, are meant for imaging colloidal (uniform) spheres. However, it can also be used to image and analyze non-uniform objects. The purpose of this project is to characterize non-uniform particle and protein aggregates' growth patterns using HVM, proving its ability to accurately image non-uniform objects. This would benefit the bio-pharmaceutical industry, where protein aggregation slows development; the proteins in the drugs aggregate which changes the effects of the drug. By improving the ability to recognize and understand particle and protein clustering, aggregation could be avoided. This paper used simulations as a proof of concept and experimental testing. Diffusion Limited Aggregation (DLA) is a growth model which when applied to a simulation of particles, produces fractal structures, similar to physical protein and particle aggregates. By scattering light with DLA aggregates, HVM can be used to image aggregates. Once images have been produced through HVM, the Effect Sphere Model (ESM) works in conjunction with HVM analysis to extract accurate information about the aggregate. With this information, the fractal dimension of the aggregate can be determined, which can then be used to discover the growth pattern of the imaged aggregate. Preliminary results look promising, suggesting that HVM can be used as a potential tool to determine the growth pattern of aggregates.

"Emo's" Potential Application for Children with Autism

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There are currently no at-home treatments for autism that use emotion recognition, animations (scenario behavioral learning), and positive reinforcement directly from the device. Therefore, a robotic dog, nicknamed "Emo", that uses Applied Behavior Analysis (ABA) treatment techniques can be created to help interpret emotions. The prototype was created with a Raspberry Pi that controlled the animations on the display and an Arduino that controlled the servos to move the physical parts. The physical structure of "Emo" involved a three-piece chassis, 2-part neck piece, screen mount, and four legs. Emo had a 7in display for users to play a "Guessing Game", where an emotion is shown, and it must match to an emoji. The first engineering goal was reached because the physical structure was created, and Emo can move in 6 set positions. However, the device is not moving autonomously, and its movements have not been tested for mobility issues. The Visual display was assessed on its functionality as a game and incorporation of ABA techniques. Many ABA techniques such as various tries given to get the right answer and displaying a winning screen were used. The display was tested using a Questionnaire on 12 participants who interacted with the device. From their feedback, the size of the "next" button on the Starting and Loading screen should be increased and the animation should include clearer signs of happiness. The device "Emo" has the potential of helping children with autism improve how they interpret their emotions through ABA behavioral techniques.

The Impact of Part-of-Speech Tagging on the Accuracy of Word Sense Disambiguation Models

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Billions of people use search engines, like Google, daily. These systems identify meanings of words using machine learning classifiers (MLCs) through a task called word sense disambiguation (WSD). MLCs are algorithms that identify patterns in data to infer the definitions of words. A task relevant to WSD is part-of-speech tagging, which identifies the part-of-speech of a word using algorithms called part-of-speech taggers (POSTs). Past research on WSD and part-of-speech tagging indicates that using POSTs while training MLCs increases the MLCs' accuracy. However, the specific changes in accuracy that different POSTs cause in MLCs is not up-to-date with the MLCs and POSTs that are currently widely used. I aimed to study the relationship between popular MLCs and POSTs to provide information that is current. I explored the effect of two different POSTs, the Natural Language Toolkit Tagger and the Stanford Tagger, on the accuracy of three different MLCs: the naive Bayes, random forest, and k-NN classifiers. I used the SemCor 3.0 dataset, and all of my objectives were met. My findings supported conclusions from Moreno-Monteagudo et al. (2006), which stated that POSTs increase the accuracy of MLCs by a marginal amount, and certain combinations of POSTs and MLCs, such as the Stanford Tagger and the k-NN classifier, are more accurate than others. My study also found that the Stanford Tagger increased the accuracy of MLCs the most, and the k-NN classifiers outperformed all other MLCs tested. There were also instances where the accuracy decreased, which may be due to overfitting.

Design and Control of a Three-DoF Ball Joint with Applications in Robotic COVID-19 Swabbing and Surgery

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Mentor: Mr. Dongdong Liu, NYU Tandon School of Engineering

This paper presents the mechanical design and control of a three degree of freedom (DoF) ball joint module suitable for use in COVID swabbing robots and surgical robots. A prototype iteration was constructed to verify the mechanism, and a final iteration was designed in CAD. The final iteration features a more compact, robust structure and significantly larger range of motion than the prototype. Configurations of the modules

with various medical and surgical tools were demonstrated as well. To create three DoF motion and overcome limitations of current medical robots, the modules incorporate two spherical gears, the cross spherical gear (CSgear) and monopole gear (MP-gear). Each MPgear transmits motion in up to two DoF, pitch and roll, to the CS-gear. With an MPgear placed on both sides of the CS-gear, which is constrained by a spherical housing, three DoF motion is achieved. Custom differential mechanisms were manufactured to drive each MPgear in two DoF. To evaluate performance, mathematical simulations of the system's inverse kinematics were conducted, and the control algorithm was implemented on the prototype assembly. Comparisons to existing medical robot actuation and range of motion capabilities confirm this mechanism's potential for extensive performance improvements in COVID swabbing robots and surgical robots.

NEW YORK – UPSTATE

Evaluating The Role for pH-Dependent Histidines to Mediate the Release of the Ebola Virus Fusion Loop Using a Molecular Dynamics Approach

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Zaire Ebola virus (EBOV) is characterized by potent outbreaks within West Africa and a mortality rate of 50-90%. Notably, Ebola's surface glycoprotein, GP, mediates membrane fusion and entry into a cell. GP is dependent on low pH for entry; however, the exact mechanism by which this enables the release of the embedded fusion loop (FL) remains unknown. To uncover the structural changes induced by low pH, two simulations of GP were run. Specifically, histidines in the proximity of the FL (123, 172, 203) were focused on because these amino acids acquire a positive charge under low pH, increasing likelihood of rearrangement needed for fusion. Therefore, in the first simulation, histidines were protonated to model low pH conditions; whereas in the control, histidines remained deprotonated. Next, we utilized a molecular dynamics (MD) tool, Visual MD (VMD), to analyze changes that may enable the release of the FL. A full structural analysis of GP was conducted, in which distances between the two amino acids and the dihedral twist of each residue was calculated. Results showed that low pH destabilizes the domain adjacent to the FL, but has a stabilizing effect on the fusion loop itself. In addition, as predicted, histidines rearrange to interact with residues of opposite charge, as evidenced by enhanced dihedral twist and closer proximity to one another. Ultimately, our study has helped develop a greater mechanistic understanding of the exact conditions required for virus entry, bringing us closer to developing antivirals that exploit this knowledge to fight EBOV infection.

The Home Application of the Freeform Reversible Embedding of Suspended Hydrogels Form of 3D Bioprinting

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Three-dimensional (3D) bioprinting, for the past decade, has been the catalyst for various advancements within the field of tissue engineering. 3D bioprinting will allow physicians to reduce the rapidly increasing demand for organs, produce new surgical approaches, develop medicines faster, as well as allow us to learn more about the human body. However, due to the expense of bioprinting technology, there are a limited number of facilities that can afford the equipment, restricting the individuals working in this field. To address this problem of limited access to bioprinting technology, a new and low-cost way to 3D bioprint at home has been created: converting a 3D plastic printer into a 3D bioprinter printer. In addition to this printer conversion, to successfully 3D bioprint a support bath/slurry must also be produced in order to maintain the intended structure of the soft materials that are being 3D printed. To produce an at-home slurry, new ingredients have been used to recreate the current in-lab support bath used. These ingredients, with the exception of GelB, are all materials that can be bought at a grocery store. The diameter of the microspheres, the polymers within the support bath, created in the at-home

support bath matched the diameters of microspheres produced in in-lab slurries. By creating a low-cost and at-home way to 3D bioprint will expose more individuals, such as high school and college students, to the 3D bioprinting technology, allowing more people to work towards the major obstacles that are currently present in the field.

Efficacy of Copper Oxide Wire Particles and Albendazole Against Gastrointestinal Nematodes in Goats

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Controlling gastrointestinal nematodes in goats is one of the greatest challenges facing goat farmers, and the issue is only rising due to the prevalence of anthelmintic resistance in parasitic populations. The purpose of this study was to determine the efficacy of copper oxide wire particles (COWP) in combination with albendazole in reducing the EPG of nematodes in goats. Naturally infected kiko goats were randomly assigned to receive no COWP or albendazole (CON;n=3), or 2g COWP in a gel capsule form as Copasure® (COWP;n=3), no COWP and albendazole(CON + alb; n=3), or a combination of COWP and albendazole(COWP+alb;n=3). Medications were administered on day 0, and fecal samples were taken on days 0,14, and 28. Samples were analyzed using the McMaster Technique to determine the approximate EPG of each sample. FEC were log transformed to normalize data, and a linear regression model was used. The mean FEC was reduced in COWP (p=0.0458), COWP+alb (p=0.0187), and CON+alb (p=.0007) groups, with FEC remaining similar in the CON group. By day 28, FEC in COWP+alb had reduced to nearly 0 epg, and a slight decrease from day 14 values was present in COWP and CON+alb groups. The FEC saw a greater decrease in the combination of COWP and albendazole than the individual medications over the course of the 28 study, making this treatment a possible option for long term reduction in GIN levels in goat herds.

Unhealthy Scrolling: Instagram Influencers Endorse More Unhealthy Food and Beverage Products Compared to Celebrities

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More than 3.5 billion people use social media globally, and food and beverage companies have capitalized on this by implementing celebrity endorsement strategies to promote food and beverage products. Due to the fast-paced culture of social media, limited research has examined celebrity and influencer product endorsements, creating uncertainty about their impacts. The present study investigated engagement rate and frequency of food and beverage endorsements on Instagram and assessed the nutritional value of products endorsed by musicians, athletes, and Instagram influencers (n=300) using the Nutrient Profile Index (NPI). Three raters coded 10% of the data to establish inter-rater reliability. Results indicate the most frequently endorsed food category is snack products, followed by energy drinks. The most common endorsers are Instagram influencers, who endorsed significantly more food and beverage-related products compared to other cohorts ($F(2, 294) = 4.989$, $p < .05$). Overall, the snack products endorsed by influencers received the lowest NPI scores and are considered the most unhealthy food category endorsed based on NPI standards (NPI scores < 64). Additionally, there was no significant difference in the engagement rate (i.e., number of likes received) of food and beverage related posts across the three cohorts ($F(2, 600) = 3.349$, $p > .05$). These results bring awareness to the physiological effects that food and beverage product endorsements may have on consumers' purchasing habits and dietary behaviors. Since celebrity and influencer endorsements are known to influence viewers, adolescents especially, the results of this study may also encourage a change in social media marketing regulations.

Developing and Assessing Fucose-Based Water-Soluble Bioplastics

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Since their invention decades ago, single-use plastics have shaped the way people live. However, in recent years, light has been shed on the dangers they pose to marine ecosystems due to released toxins. Despite the environmental hazards surrounding single-use plastic waste, there is little research regarding the development of water-soluble bioplastics from renewable sources to mitigate these effects. The purpose of this study was to develop water-soluble bioplastics from algae and other natural materials. This work expands upon previous methods of developing bioplastics, but the composition of the polymer itself is novel. It was hypothesized there would be a difference in the dissolution and pH alteration of the fucose-based products in comparison to previously developed PVA-based plastics. Four trials were performed, each with varying amounts of fucose by mass. Additionally, these trials were directly compared to previously studied polyvinyl alcohol-based plastics with different compositions of PVA by mass. Each product was tested in both freshwater and 3.5% saline media; pH level was recorded after each 24-hour interval. I found that the 90% fucose-based plastic dissolved the most with 63.24% dissolution; this was less than the 72.55% of the 90% PVA plastic's dissolved mass. Chi-Square tests comparing the fucose and PVA plastics, showed no significant difference in the dissolutions. The PVA plastics did not significantly alter their freshwater environments' while the fucose-based plastics significantly altered pH after both 24 and 48 hours of testing, as supported by P values of 0.0002 and 0.001, respectively.

NORTH CAROLINA

Assessing the Efficiency of Copper Thermoelectric Generators Compared to the Industry Standard of Ceramic

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With global calls to better conserve energy, current computer systems have been a large adversary to the effort. Computer systems, however, have a centralized heat source that can be converted to energy through Thermoelectric Generators, also called TEGs. TEGs have been relatively unused due to their low efficiency levels, at about only 5-8% of heat to energy. This has also led to TEGs being unresearched despite their potential. Even with low efficiency, TEGs have several advantages to implementation such as easy installment, little maintenance due to no moving parts, and their ability to create energy with just the temperature input. Thermoelectric generators are currently only widely used in extreme conditions such as on military and aerospace equipment, where the significant temperature difference needed to generate useful energy is present. Our study aimed to reduce the extreme conditions required to make TEGs beneficial by determining the most efficient TEG type between the two most commonly manufactured, the industry standard of ceramic and copper, and allow their implementation on a larger scale. We tested the different TEG's voltage outputs at certain temperatures which were pegged to the average CPU temperature at differing usage levels of personal and industrial computer systems. We found that ceramic TEGs would be more effective for personal devices due to higher voltages at lower temperatures compared to copper. However, ceramic hit a threshold and became less efficient at around 100°C whereas copper TEGs continued to increase voltage levels past 100°C, making it viable for industrial use.

Continuous Oral-fluid Monitoring of Glucose (O.M.G.) Device with Near Field Communication Capability

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Mentor: Dr. Xuan Mei, Harvard University

Around 34 million Americans have Type 2 Diabetes (T2D), while 88 million American adults have prediabetes. Different from the traditional invasive needle method, my proposed salivatory glucose-monitoring device,

named OMG, can facilitate self-monitoring through a noninvasive method by using cost-effective material and Near Field Communication (NFC) chips. The electrodes that I designed were coated with Glucose Oxidase (GOx), where a biological redox reaction occurs after being in contact with salivary glucose. When the interdigitated electrode (IDE) connects to an NFC tag, the redox reaction strongly changes the impedance of the tag, modulating the electromagnetic reflection from the tag, and reflecting it as the "change of frequency" (which is proportional to the glucose concentration). Afterward, I used both commercial chemical methods and ex-vivo to assess viability and usability, same to in vivo styles. Data were assessed by creating several separate comparisons between OMG and Glucose Colorimetric Assay. SEM images captured GOx's morphology, Vector Analyzers were used to collect data, and Glucose Assay Kit (Colorimetric) was used for comparison between commercial and OMG. Saliva was collected through regulated protocols and GraphPrism. The results suggest that the trendline is reliable (R^2 = 0.9292) for OMG readings and (R^2 = 0.8692) for our Performance Tests, which is also comparable to the commercial method. Conclusively, the non-invasiveness and portability demonstrate the necessity of developing such applications.

Quantifying Nature's Ability to Clean Up Soil Contamination 20 Years after a Major Factory Burning

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Mentor: Dr. Bailey, Assistant Principal, Charles D. Owen High School

Twenty years ago in our town of Swannanoa, North Carolina, Beacon Blankets, a blanket factory that ran for more than 100 years and employed generations of people in the Swannanoa and Black Mountain area, was subject to arson and completely burned down. It has been left abandoned. A study was conducted to learn how nature has recovered from this incident by testing the soil and comparing it to local untreated soil in a similar environment. First, soil was acquired by mapping the Beacon factory land in fourteen different quadrants and obtaining soil from three-six inches deep. Next, local soil was acquired at the same altitude that was also untreated and in an open field. The soil was assessed for pH using a soil pH test. Then, the soil was tested for nitrogen, phosphorus, and potash using a soil test kit. These compounds were tested because high levels are needed for plant growth and healthy ecosystems. The results showed an average of 6.89 pH which is healthy, but compared to the control, all quadrants of soil from the factory had low nitrogen, phosphorus, and potash levels. With these results, it was determined that without human intervention for 20 years, nature has been unable to produce healthy soil after a catastrophic burning event.

The Effect of Rider Ability and Movement on the Stress/Discomfort Indicating Behaviors of Hippotherapy Equines

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A majority of hippotherapy patients struggle with balance, coordination, and self-regulation, causing participating horses to present stress/discomfort indicating behaviors (SDIB) during therapy sessions. Hippotherapy uses horses and their movements in therapeutic settings; benefits include fine-motor development and increased mobility. This study aimed to (1) identify which therapeutic activities result in a higher number of SDIB, and (2) find differences in the presentation of SDIB in horses when a therapy patient rides versus an experienced rider. A Therapy Patient and an Experienced Rider rode the same 7 horses and completed the same activities on each horse, all while being videoed. The first activity was mounting the horse, the second activity was crossing an elevated platform, and the third involved the rider placing plastic rings on a pole to the side of the horse. After all rides were completed, an ethogram was used in order to track occurrences of 5 predetermined SDIB (tail flicking, head tossing, stomping, biting threats, and ear-pinning) during each ride. Statistical analysis provided evidence that more SDIB were presented during the mount and ring activity than the elevated platform activity, as the former require more lateral (side-to-side) rider movement. Additionally,

horses presented significantly fewer SDIB with an Experienced rider than with a Therapy patient. With results indicating that therapeutic activities and rider ability have a relationship to equine SDIB, therapists can develop goals that help improve core strength while strategically placing lateral movements throughout sessions, minimizing equine stress/discomfort.

An Investigation of the Antagonistic Effects of Rapamycin and Fructose on the Longevity of *Caenorhabitis Elegans*

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Mentor: Kimberly Monahan, Chair of Biology, North Carolina School of Science and Mathematics

Obesity persists to be one of the most prevalent causes of premature death, killing over 2.8 million people a year. Diets high in fructose have been suggested to be a cause of obesity, by increasing fat deposits and thus decreasing lifespan. To model human lipid storage, scientists have used *C. elegans*, a nematode proven to be a great model organism for both lipid storage and longevity. In *C. elegans*, fructose has been proven to activate TORC1, a complex known to promote lipogenesis. To quantify the effect of different fructose concentrations and rapamycin on the lipid storage of *C. elegans*, various amounts of fructose were added to OP50, in concentrations of 0-10% with or without rapamycin. A lipophilic dye (Nile Red) was applied to measure the amount of fat deposits for each treatment. *C.elegans* treated with lower levels of fructose did not lead to a significant increase in intestinal fat deposits until a 7% concentration; exposure to rapamycin mitigated the effect of fructose on IFDs. In order to study lifespan, *C. elegans* were treated with 0%, 3%, 7%, and 10% fructose with and without rapamycin. After 31 days, rapamycin prevented the lifespan-decreasing properties of a high fructose diet, and added to the lifespan-increasing properties of a low fructose diet. Overall, these experiments suggest rapamycin as a treatment to both the fat-increasing and lifespan-decreasing effects of a high fructose diet. This treatment has the potential to reduce obesity on an international scale, and can serve to lengthen the human lifespan.

NORTH CENTRAL

Overcoming Opioids: Analyzing, Characterizing, And Quantifying the Sentiment of Reddit Posts' Tone and Language Prior to a Relapse to Allow for Early Intervention

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Teacher: Princesa Hansen, Wayzata High School
Mentor: Dr. Stevie Chancellor, Assistant Professor, University of Minnesota

Sixteen million people worldwide have suffered from opioid use disorder (OUD). Many of those affected by OUD turn to social media, particularly Reddit (a popular online-based post forum) as a means to aid them in their journey to recovery. The purpose of this study is to characterize how an individual's vocabulary and tone changes in their Reddit posts as they move towards an opioid addiction relapse. The long-term application of the project is to evaluate if a potential opioid addiction relapse can be prevented by recognizing warning signs in Reddit conversations by identifying a pattern in user's posts.

The first step involved identifying Reddit users who had self-disclosed a relapse in the subreddit r/OpiatesRecovery. This was done by building three language matching systems, known as regular expressions, which considered language differences between people and accounted for multiple variations of the same phrase. The regular expression with the highest occurrence was a form of the phrase, "X days clean", appearing 806 times in 16,432 posts retrieved from Reddit's public API from 2012-2021.

10% of users on this subreddit, originally meant for recovery, self-disclosed that they relapsed. On average, users who divulged their relapse went on to discuss it in 39% of their overall posts. 36% had their first post on the subreddit discuss a prior relapse.

This research demonstrates a promising effort in developing automated identification of recovery problems that could allow professionals to efficiently engage with users who are struggling, and provide them with timely and accurate support.

Effect of Ethanol and Octocrylene on the Cell Growth and Chlorophyll-a Levels of *Cyclotella meneghiniana*

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Mentor: Prof. Matthew Julius, St. Cloud State University

This study aimed to determine whether exposure to environmentally relevant levels of octocrylene, a common sunscreen chemical, harms the overall health of the freshwater diatom *Cyclotella meneghiniana*, measured by decreased cell density and chlorophyll-a levels. Axenic cultures of *C. meneghiniana* were exposed to three concentrations of non-water-soluble octocrylene (0.03, 0.3, and 3 µg/L) dissolved in ethanol over six days. To ensure that observed effects were due to octocrylene and not ethanol, two control cultures were included: C-Blank with no chemical additions and C-Ethanol with the highest concentration of ethanol exposure used in the 3 µg/L condition. Cell densities and chlorophyll-a levels were measured using a Palmer-Maloney cell and a Turner fluorometer before and after the six-day exposure. Compared to the C-Blank control, the cell density and chlorophyll-a levels in the C-Ethanol condition were significantly lower (t-test, $p=0.01$ and $p=0.0002$, respectively). The C-Ethanol measurements were statistically similar to those in the 3 µg/L group (p = NS). These data demonstrate that exposure to the ethanol solvent significantly reduced cell densities and chlorophyll-a levels in *C. meneghiniana.* Therefore, the independent effect of octocrylene on the cell density and chlorophyll-a levels could not be discerned in this study.

Using Monte Carlo Simulation to Optimize Vitamin C Production in *Brassica oleracea* Using Abiotic Plant Stress

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Advisor: Betsy Hughes

As the world population increases, so does the global demand for food. Simultaneously the quality of Earth's farmland is declining. To fill this need, the agricultural industry has been revolutionized through vertical farms (VF), where crops are grown indoors without sunlight or soil. However, there's a downside as experiments have shown that VF crops contain less Vitamin C compared to conventionally grown crops. The lack of stress in the typical VF environment inhibits the ascorbate-glutathione cycle in the plants, which is the pathway to Vitamin C production. This study aims to grow *Brassica oleracea* in stress-controlled environments (in the form of wind, heat and drought) and to use that data to find the ideal combination of stress levels to optimize Vitamin C production using Monte Carlo Simulation. It was hypothesized that the Vitamin C levels of *Brassica oleracea* could be increased and raised to a level equal or superior to that conventionally farmed. The secondary hypothesis is that the optimal combination of stress levels can be found using Monte Carlo simulation. After a t-test and regression analysis, the Vitamin C levels of all groups were proven to be statistically significantly lower (alpha = 0.05) than that of the control group except the group P3G1 (eight hours of daily wind and 32.2° C), which was non-inferior to the control, therefore the null hypothesis is rejected in favor of the alternate. The simulation successfully identified the optimal stress combination of 11 hours of wind stress at 35°C. Further testing is needed.

Cure of Breast Cancer - Year 5: A Novel Approach to Treating Hormonal Breast Cancer Using Diabetes Medication Through Clinical Database and 3D *ex vivo* Model

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Type 2 diabetes (T2D) female patients have a higher risk of being diagnosed and have worse survival for breast cancer compared to non-diabetic females. Although the relationship between these two female diseases has been reported, specific functional studies on which subtypes of breast cancer are affected and which genes are regulated by T2D are little known. Here, I found that Forkhead Box A1 *(FOXA1)* and Metformin, anti-diabetic medication for T2D, affect hormonal positive (HR+) breast cancer tumor cell growth and metastasis. 14 diabetes-related genes highly expressed in three HR+ breast cancer cell lines but not other breast cancer subtypes using a 53,805 gene database obtained from NCBI GEO. Among the diabetes-related genes, *FOXA1*, *MTA3*, *PAK4*, *FGFR3*, and *KIF22* were highly expressed in HR+ breast cancer from 4,032 breast cancer patient tissue samples using the Breast Cancer Gene Expression Omnibus. Specifically, the high expression of *FOXA1* correlated to a worse ER+/PR+ breast cancer patient survival rate. Consistent with this, the loss of *FOXA1* inhibited the tumor proliferation and invasion of MCF-7 and T47D HR+ breast cancer cell lines using *in vitro*. Metformin (1,1-dimethylbiguanide hydrochloride) conspicuously inhibits the tumor cell growth in MCF-7 human hormonal breast cancer cells. Metformin or *FOXA1* deletion enhanced Tamoxifen-mediated tumor growth inhibition in HR+ breast cancer cell lines through the *ex vivo* three-dimensional (3D) organoid model. Therefore, HR+ breast cancer is closely related to T2D, and metformin and *FOXA1* inhibition might be an optimal new treatment for patients with HR+ breast cancer when combined with tamoxifen, a hormone therapy.

Immune System Innovation: Ushering in A New Era of Immunology Research by Characterizing Cell Populations Most Impacted by Normal Microbial Exposure for Preclinical Research and Healthcare Treatment Development Success

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Teacher: Ms. Princesa VanBuren Hansen, North Star Online

Mus musculus (mice) are often used to model the human immune system and to develop healthcare treatments because mouse immunology accurately recapitulates many aspects of the human immune system. However, differences between the immune systems of lab mice and the true human immune system may decrease the predictive power of treatments developed in mice. One limitation of using mouse models to study human immune conditions is the relative immune immaturity of laboratory mice. Immune maturity is a key component in any organism's ability to resist disease and infection.

This project aims to redefine treatments geared towards infant human immune systems by showing that normal microbial exposure (NME) mice, which have undergone microbial exposure from conception, have an accelerated immune development relative to their specific pathogen free (SPF) counterparts and thus more accurately model human immune development. For this work, tissue samples from 120 mice were characterized.

The hypothesis was supported, indicating that the use of SPF conditions for laboratory mice in preclinical and research studies leaves the immune systems of infant mice underdeveloped and far different from those found in human infants. The data presented herein further demonstrated that infant NME mice develop elevated profiles of numerous immune components during different stages in development and better reflect human infant immunity. Applying *Listeria monocytogenes* challenges or sepsis challenges to NME mice in the future will demonstrate the physiological changes associated with the changed immune composition. This work is critical in advancing immunology research and accurately developing preclinical healthcare treatments.

OHIO

Ceres: A Novel Device Utilizing Raspberry Pi & Neural Networks to Detect Crop Diseases Using Imaging

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Globally, food demand is increasing; at the same time, about 10-20% crop is damaged/wasted during production/harvest due to pathogens. This could be reduced with early detection of crop diseases. Current methods rely heavily on time consuming processes of lab testing/expert validation. Ceres, the proposed solution, is an affordable, accurate, scalable device to detect the crop diseases infield/onsite. Early detection helps take preventative measures to stop disease spread. Ceres was trained using the images collected from the growers/universities. These images were validated by the experts. In total, about 13,000 images were collected/validated across 14 crop/fruit/vegetables and 24 diseases. The Ceres model consisted of a total of 12 layers of 6 distinct types for training. A median filter and feature extraction were used so that the model can focus on the contents of the image. For validation, it was fed images which were not seen earlier. The training and validation images were divided in 70%/30%. The validation results suggest that Ceres has accuracy of 89% with F-score of 92.4. The Ceres physical device is easy to use - where the user captures the image, it is analyzed within 2-3 seconds and results are displayed on the screen. Ceres consists of a 3D-printed device, a Raspberry Pi, camera, LCD, and a button to take the image. Overall, Ceres was able to completely fulfill its design criteria. In conclusion, this project shows that a neural network with multiple layers can be developed in conjunction with a physical device for early detection of crop diseases.

Developing Propellers with a Fringed Trailing-Edge Inspired by Owl Flight to Reduce Noise

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Teacher: Dr. S. Laux, University School

Of the many origins of noise, aerodynamic fans and propellers are significant contributors, such as the ones used in ventilation, aircraft, and electrical generation. Fans and propellers produce noise in many spots throughout blade, but a considerable amount is produced at the trailing edge. Owl wings are well-known for their ability to minimize the turbulence all while preserving aerodynamic efficiency through unique features, one of which are fringes at its trailing edge. The use of this feature was tested to predict the reduction of noise in man-made propellers. Two 17.5 cm propellers were designed by the author in a modeling software (Blender) and 3D printed. Each blade was experimented on a 3V DC motor with two 1.5V AA batteries providing 3V at 900 RPM. Data was acquired using MacBook Pro microphones and Sound Meter, a decibel meter application. Each sample was 60 seconds, and data was recorded every 1 second. An independent sample t-test was performed to compare the decibel between the control propeller and the modified propeller. There was a significant difference in decibels between the control propeller ($\dot{x}$ = 27.00, SD = 0.527) and the modified propeller ($\dot{x}$ = 26.19, SD = 0.707); $t(118) = 7.0514$, $p = <0.0001$). This study showed that fringed propellers using fringed trailing edges inspired by owl wings are quieter than non-fringed propellers. The noise reduction was approximately 0.81 dB. Further testing will allow its use in practical applications such as drones, ventilation, and similar small-scale uses.

PRO or NO Biotic: Survivability of *Lactobacillus Rhamnosus* in the Large Intestine with the Use of Amoxicillin

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Teacher: Mr. McCray, Tippecanoe High School

The use of probiotics with prescribed antibiotics is a rapidly evolving field in gastrointestinal research. Limited in-vivo research has suggested that the use of clinical probiotics is effective in reducing destructive effects of

antibiotics on the microbiome. However, a majority of these studies used antibiotics and probiotics sequentially, not simultaneously. This experiment used a simplified in-vitro model of the human digestive process to determine the survivability of the probiotic strain *Lactobacillus Rhamnosus* when taken in concurrence with amoxicillin. It was hypothesized that the highly acidic concentration of the stomach and the corrosive digestive enzymes found in the small intestine would reduce observed colonies of Lactobacillus. In testing, four beakers were used to simulate the major parts of the digestive system. A *Culturelle*® probiotic tablet was introduced to the system and two hours later an amoxicillin pill was introduced and the process continued accordingly. Another *Culturelle*® tablet was used, "restoring" lactobacillus to the colon. The contents of each beaker was swabbed onto an MRS agar plate. There was inconsequential lactobacillus growth found on any plate after exposure to stomach acid. This experiment demonstrated that *Culturelle*® probiotics capsules do not survive the harsh conditions of the stomach. Simulating only the large intestine, a similar method was used. The colony count decreased by more than ninety-two percent when an antibiotic was introduced and increased minimally when the second probiotic was added. This suggests that it would be most effective to take probiotics once antibiotics have begun to cycle out of the digestive system.

Development of a Generic Nanophotonic Processor using Programmable Photonic Integrated Circuits (PPICs)

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Computing has become a pillar in propelling much of the modern progress scientific progress for more than half a century. However, exponential trends within digital electronic computing systems in traditional, silicon-based transistor technology has, over this decade, sharply declined. The firmly established paradigm of miniaturization and scaling of transistors is approaching fundamental physical limits. Without a viable alternative form of computing to address the physical limitations of transistors, this threatens to slow progress within both the semiconductor and microelectronic industries. The goal of this engineering paper was to design a proof-of-concept generic nanophotonic processor that addressed the inherent scaling issues with microelectronics while providing greater computational performance. The hardware elements on the nanophotonic processor were designed and optimized through finite-difference-time-domain (FDTD) and finite-element-method (FEM) simulations. Software control algorithms with graph theory were implemented for the routing and processing of optical signals. With this, three key optical path distribution problems were addressed using graph theory and iterative heuristic algorithms: the Single Input-Output Pairs, Multiple Input-Output Pairs, and Single Input With Multiple Outputs problems. Additionally, a new fabrication tolerant waveguide mesh was designed for the implementation of the photonic components on a silicon-based platform. From the simulations, it was determined that the theoretical operational frequency of the nanophotonic processor was 79.52MHz. The software control algorithms had an average duration 0.003664 seconds to calculate an optical path, which was shown to be 13.3 times faster than algorithms previously developed.

Epidemiology of Pineoblastoma in the United States, 2000-2017

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Pineoblastoma (PB) is a malignant brain tumor that originates in the pineal gland. Patients diagnosed with PB experience headaches, sleepiness, vomiting, and vision changes. This epidemiological study was performed to determine at-risk populations, treatment, and prognosis. Data on 1,178 patients with PB were acquired from the Central Brain Tumor Registry of the United States (CBTRUS) from 2000-2017. PB was defined by the International Classification of Diseases for Oncology (ICD-0-3) code 9362/3 and primary site code C75.3. Frequencies and age-adjusted incidence rates and rate ratios per 100,000 were calculated using SEER*Stat. Median survival and survival curves were generated using the NPCR survival database. PB occurred equally in females and males. The incidence rate of PB decreased as age at diagnosis increased with the highest

incidence at 00-04 years (AAIR: 0.05, 95% CI: 0.043-0.058). There was a higher frequency in white patients (71%) compared to black patients (23%) although the incidence rate ratio was higher for black patients (AAIRR: 1.698, 95% CI: 1.473-1.954, p< .0001). The incidence rate ratio of black patients stratified by age was highest in pediatric patients 5-9 years (AAIRR: 3.5532, 95% CI: 2.4627- 5.1027, p< .0001). However, as age at diagnosis increased, the incidence rate ratio decreased. Survival was lower among patients who did not receive surgery (p=0.001), males (p=0.021), and lowest in children ages 0-4 (p<.0001). This study proposes the most current and comprehensive analysis to provide vital information for current clinicians, public health planners, and patients to improve diagnosis and patient care.

OREGON

Products of Reflections in Smooth Bruhat Intervals

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Teacher: Purushottam Goel, Krishna Homeschool
Mentor: Christian Gaetz, Postdoctoral Fellow, Harvard University

My research deepens connections between the two seemingly very different mathematical fields of algebraic combinatorics and algebraic geometry. In particular, I focus on the Bruhat order, a well-studied partial order structure in algebraic combinatorics, and deepen its relation to the algebraic geometric notion of smoothness. My main results show how chains in this Bruhat order emerge from smooth elements. I used this discovered structure to provide a new criterion for smoothness. Finding new criterions for smoothness has been a subject of many recent papers, and my results directly contribute to this effort, increasing possibilities for further study at the intersection of combinatorics and algebraic geometry.

Outside pure mathematics, my research also has potential for a broader societal impact through the lens of physics. I build on methods used in cutting-edge research to analyze the amplituhedron, a geometric structure which is a tool in quantum field theory (QFT) and particle scattering. My research shows that the chains of the edges satisfy previously unknown relations, and could combine with other mathematical physics results in the near future to exponentially speed up computations of edges in the amplituhedron. Faster computations on this structure would lead further advances in QFT, thus deepening our knowledge of the subatomic nature of the universe. This research, by potentially advancing QFT, has proven potential for benefitting technologies in medical imaging, superconductivity, and more.

SarcoSeg: A Convolutional Neural Network-based Sarcopenia Analysis System via Automatic Segmentation of Skeletal Muscle and Adipose Tissue in Cervical Computed Tomography Towards Precision Medicine Applications

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Sarcopenia, a condition distinguished by a reduction in skeletal muscle mass and function, significantly impacts the treatment success and survival-rate of over 50 million people. To diagnose sarcopenia in patients with head and neck cancer (HNC), skeletal muscle index (SMI) is measured from computed tomography (CT) of the cervical spine. However, this requires time-consuming manual segmentation which is unrobust, unquantified, and prone to inter-operator variability. In this research, a deep learning-based approach is developed for automatic sarcopenia diagnosis at the third cervical vertebrae level. Contrast-enhanced CT scans from 394 population-representative HNC patients at a single institution were utilized. First, single-slice selection and ground-truth skeletal muscle and adipose tissue annotations were manually performed on each scan. Then, a two-dimensional U-Net deep learning architecture, SarcoSeg, was built to auto-segment muscle and adipose from scans. SarcoSeg uses Sørensen–Dice coefficient generalized loss to alleviate class imbalance. From segmented cross-sectional

area (CSA), SarcoSeg calculates SMI to predict sarcopenia status. Statistical analysis shows that SarcoSeg is a promising method for predicting sarcopenia from CT. Linear regression comparing SarcoSeg's predicted segmentations to radiologist ground-truth segmentations of skeletal muscle and adipose yielded R-squared values of 0.96 and 1.00 respectively. In predicting sarcopenia, SarcoSeg's specificity and positive predictive value were measured to be 0.98 and 0.96 respectively. Cohen's kappa between the SarcoSeg sarcopenia diagnosis and ground-truth was measured to be 0.80, suggesting excellent agreement. This study enables oncologists to make quantified sarcopenia-related decisions for HNC patients towards precision care and improving quality-of-life and survival-rate.

Boundary Detection of Debris-Covered Glaciers Using Fractal Analysis and Normalized Differencing of Thermal and Infrared Bands in Remote-Sensed Landsat Datasets

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The importance of studying glacial melting to understand the impact of climate change is amplified by number of glaciers in the world and complicated by the feasibility of monitoring them individually. Remote sensing techniques such as multiyear satellite imaging provide a valuable dataset for such comprehensive surveillance. Prior work by the author demonstrates the utility of fractal analysis of glacier Landsat images to serve as a predictive indicator of glacial melt. Critical to such analysis is a clear delineation of glacial extent and boundaries. The complexities of determining glacial extent of debris-covered glaciers are considered in this study to explore methods of delineating the boundaries of such glaciers. Debris-covered glaciers present unique challenges to identifying glacier presence and glacier edges as the underlying glacier is not readily evident. Understanding and characterizing these features are important for several reasons, including preparedness in regions prone to glacial lake outburst floods. This study combined normalized differences of moisture and thermal band data with fractal analysis of the resulting datasets to impute boundaries of debris-covered glaciers. It further attempted to delineate these boundaries for the world's youngest glacier – the Crater Glacier in Mt. St. Helens in Washington, USA. The results also show promise in determining glacier boundaries of debris-covered glaciers and demonstrate that the fractal dimensions of such boundaries may be indicative of sub-surface water ($p < 0.001$). Confirmatory analysis was performed by comparing the imputed boundaries with those gleaned by surface LiDAR surveys, and these reveal adequately close approximation of the imputed boundary.

A Novel Machine Learning Based Identification Tool (ELECT) for Early Colorectal Cancer Detection Through Advanced Microbiome Composition Analysis

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Mentor: Zheng Xia, Ph.D., Assistant Professor, Department of Computational Biology; Department of Molecular Microbiology and Immunology; Knight Cancer Institute, Oregon Health & Science University

Colorectal cancer(CRC) ranks third in occurrence and second in mortality among all cancers. Current CRC identification methods are often ineffective due to the invasiveness of such procedures and long waiting times for test results. Most CRC cases are identified in the late stage which has a drastically low 14% 5-year survival rate(5ySR). However, if found at early stages, the 5ySR of CRC cases is around 90%. Thus, early cancer detection is crucial to preventing CRC deaths.

The ELECT project's goal is to accurately detect CRC early on and identify high-correlation cancer biomarker flags. It utilizes an elastic-net regression machine learning model to predict cancer risk based on microbiota samples. Incremental hyperparameter tuning and feature selection were run simultaneously to select the best performing model and increase correlation score. The model was trained, validated, and tested on over 1.5 million unique gut bacterial oncology samples for robustness.

After cross-validation, the final model was able to predict CRC with an accuracy greater than the current industry best by 9%. Model results in statistical cluster plots and heatmaps further demonstrate precise and accurate predictions. In addition, this model significantly reduced the dataset size needed by 99% – shrinking the initial pool of 5207 bacteria types needed to 43 of the most critical bacteria biomarkers.

This research allows oncologists to quickly, non-invasively, and accurately identify at-risk CRC patients early yielding a greater cancer survivability. Project future work focuses on identifying CRC recurrence and piloting in clinical trials for application to real patient-cases.

OncoML: A Multi-omics-based Ensemble Learning Approach for Targeted Cancer Drug Prediction

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Predicting the response of a cancer patient to a specific drug is a major goal in precision oncology. The current approach to cancer treatment is a one-size-fits-all approach, failing to comprehend tumor heterogeneity, results in 75% ineffectiveness of cancer treatment. The availability of large computing cycles has allowed the creation of high-throughput genomic technologies and large-scale sequencing studies including The Cancer Genome Atlas (TCGA). Recent research has focused on modeling of drug prediction by applying machine learning on genetic mutations or using microRNA (miRNA), a key biomarker of cancer, on mice models or cancer cell lines (Kalamara et al., 2018). Although these approaches demonstrate improved potential of targeted drug prediction, they present some limitations. Gene mutations have shown to account for a subset of candidate biomarkers, while miRNA-based gene expression is regarded as offering more predictive modalities; both can be complemented by the multi-omic view of cancer. The integration and analysis of these multi-omics data is a critical step to deliver on the promise of precision oncology: selecting drugs for patients based on their individual data. The solution is a machine learning platform that analyzes genetic mutations, miRNA, and other pharmacogenomic data of various cancer types of real patients and predicts targeted drugs for any given cancer patient with a high accuracy. This approach of using machine learning on multi-omics cancer data of real patients from The Cancer Genome Atlas to deliver targeted cancer drug therapy is superior to existing mono therapy research on cancer cell lines.

PENNSYLVANIA

The Effects of a Novel CRISPR-Cas9 System in Human Cancer Cells

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Current treatment options for lung cancer are often ineffective and nonselective, causing severe side effects and damage to healthy respiratory tissue. However, considering that cancers are caused by DNA mutations, gene therapy is now at the forefront of treatment research, and CRISPR/Cas9 may be the most accurate, fast, and cost-effective method. In this novel experiment, the effectiveness of this technology in combating tumor development was measured by using Cas9 and sgRNA molecules to target flanking ends of key exons in TERT and KRAS, intercorrelated oncogenes that promote unregulated growth and proliferation, in A549 lung cancer cells. One culture of cells was exposed to only TERT removal, another to only KRAS inactivation, and a third to targeting of both genes. Cell death rates were quantified through the trypan blue exclusion assay, while mitotic indices were calculated by observing the number of dividing cells in a constant sample size. The results supported the hypothesis, as they revealed that in comparison to the control, the groups that experienced a loss of function in both genes simultaneously consistently exhibited the highest rates of cell damage and the lowest percentages of proliferation, while those who had solely one of the genes disabled also displayed antitumoral

effects, but to a lesser extent. Microscopic analysis further proved that by disrupting the expression of both oncogenes at the same time, the dual-CRISPR/Cas9 system most efficiently activated intracellular apoptotic pathways and helped the cell resist pro-mitotic environmental cues.

A Mathematical Approach to Constructing Special Four-Way Factorable Quadratics

Sarah Huang
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Mentor: Professor Philipp Rothmaler, Bronx Community College

When I first learned how $x^2 \pm 5x \pm 6$ can factor with interchangeable signs, I was fascinated with its simplicity and orderliness. I was curious to know if there would be more quadratics that could factor in four ways like this and how we could find them. Inspired by that, this paper aims to find a mathematical approach to construct four-way factorable quadratics and explore the relationships between factors and polynomials. It was hypothesized that there are unlimited numbers of such four-way factorable quadratics which share certain patterns. To test this hypothesis and study the relationships, a solvable mathematical model was established with six variables. Geometric visualization and computer programming were also utilized for identifying patterns and inspiring future exploration. By proving the rationale of the mathematical model, simplifying the six variables back into two, and analyzing the relationship of the remaining two variables, the existence of unlimited numbers of four-way factorable quadratics was confirmed. During the investigation, the patterns of such four-way factorable quadratics were also identified, which can be applied to look for all the admissible quadratics given a certain range. This research serves as a catalyst for further investigations of various natures and other patterns of polynomial factoring. In addition to using a complex formula to solve the roots of a quadratic, factoring can be connected to the shape of a polynomial, geometry, and computer programming. The thinking process and conclusion of this study hopefully will inspire middle school and high school students to view factoring in a different light.

The Bio-Battery: Investigating an Organically-Based Electrochemical Cell

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For the past 50 years, lithium-ion batteries have dominated portable electronics (phones, laptops, tablets, etc). However, their use comes with many risks. Most lithium-ion batteries utilize lithium cobalt oxide, a known human carcinogen. Further, lithium, cobalt, and nickel production is linked to unethical mining practices, where large corporations exploit disadvantaged workers. Organic electrochemical cells (OEC) can be used to overcome these issues. This research proposes a novel OEC with the use of non-toxic, biodegradable, and biologically derived materials. The Spartan Molecular Modeling software was used to assess the performance and compatibility of materials. Thermodynamics, voltage, solvation energy, molecular structure, and HOMO/LUMO values were evaluated using this software. It was determined that a potassium-ion-based system with a 1,4 benzoquinone (BQ) cathode and a dipotassium terephthalate (K2TP) anode would provide the best results. BQ was found to have a theoretical capacity of 287 m.Ah.g-1 and redox potential of 2.8 V. The low redox potential of K2TP (0.6 V) is optimal for a higher working voltage of the overall battery. To support this system, a cytochrome c current collector, N-Methyl-N-propyl piperidinium bis(trifluoromethanesulfonyl)imide ionic-liquid electrolyte ([PP13][TSFI]), and Peptidoglycan-Polyacrylic Acid (PG-PAA) binder were proposed. This research introduces new biopolymers and biomaterials for use within solid-state electrochemistry. However, to expand the use of OEC into high-demand electronics, more research must be done to perfect the functionality of the battery, particularly for the current collector and cathode.

Using Machine Learning to Augment Dynamic Time Warping Based Signal Classification

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Modern applications such as voice recognition rely on the ability to compare signals to pre-recorded ones to classify them. However, this comparison typically needs to ignore differences due to signal noise, temporal offset, signal magnitude, and other external factors. The Dynamic Time Warping (DTW) algorithm quantifies this similarity by finding corresponding regions between the signals and non-linearly warping one signal by stretching and shrinking it. Unfortunately, searching through all "warps" of a signal to find the best corresponding regions is computationally expensive. The FastDTW algorithm improves performance, but sacrifices accuracy by only considering small signal warps.

My goal is to improve the speed of DTW while maintaining high accuracy. My key insight is that in any particular application domain, signals exhibit specific types of variation. For example, the accelerometer signal measured for two different people would differ based on their stride length and weight. My system, called Machine Learning DTW (MLDTW), uses machine learning to learn the types of warps that are common in a particular domain. It then uses the learned model to improve DTW performance by limiting the search of potential warps appropriately. My results show that compared to FastDTW, MLDTW is at least as fast and can have up to 25.9 times less error on a real-world data set. These improvements will significantly impact a wide variety of applications (e.g. health monitoring) and enable more scalable processing of multivariate, higher frequency, and longer signal recordings.

The Effect of Electrical Stimulation on Ethanol-Induced Paralysis Modeling Parkinsonism in *C. elegans*

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Supervisor, D. Rosensteel, State College Area High School

Parkinson's disease and similar neurodegenerative conditions like Parkinsonism, currently affect a large portion of the senior population and in some cases, have limited treatment options. However, methods exploiting applied electrical potential have shown promising results. In order to better understand these methods, this study was designed to model drug-induced parkinsonism in the roundworm organism *C. elegans* that mimic humans within a neurological scope. Experimental groups received different combinations of ethanol to induce the paralysis and tremor associated with the disease and electrical stimulation via copper electrodes and a basic power station for a duration of 20 minutes. The locomotion of the *C. elegans* was recorded and quantitatively analyzed for body bends and survival time. ANOVA and Tukey HSD tests revealed p-values less than 0.0001 for both variables of interest and further analysis of means identified prolonged survival in *C. elegans* receiving electrical stimulation. The findings of this study can be further expanded upon in professional settings using more comprehensive lab techniques to provide greater insight into this method of treatment for Parkinson's-like diseases.

PHILADELPHIA

A Novel Anthropomorphic Myoprosthesis for Transradial Amputees

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Dr. Jennifer Collinger, University of Pittsburgh Rehabilitation Neural Engineering Laboratory

Currently, prosthetics are more mechanical apparatuses than a viable replacement for the human hand. There have been several iterations of prosthetics over the years, but no prosthetics have been able to replicate the

dexterity and biological properties of the human hand at a low cost. This project is a non-invasive myoelectric hand and wrist prosthetic unit that combines both rigid-body and compliant parts to allow for the actuation of 10 anthropomorphic joints, and a wrist capable of flexion and adduction of 60 degrees. After performing amputee tests, the prosthetic was able to restore 70\% of the range of motion of the human hand on average. The device takes only 2 hours on average to learn to use. This device was 3D-printed using a Form 2 and an Ultimaker 2+ Connect with flexible and tough resin, ABS, PLA, and semi-flex filaments to confer high dexterity and stability. A custom PCB was fabricated to support a spectral analysis algorithm to decode surface EMG with a 94.6\% accuracy. The cost of building the prosthetic was $876.33. This project will serve as a reference to developing more low-cost prosthetics in the future; I have already begun corresponding with disability organizations such as the Amputee Coalition, Microsoft, and Billion Strong to continue feedback and testing cycles with amputees. The prosthetic design has also caught the attention of Hanson Robotics. They are helping to communicate and outsource the work to NGOs and looking at using some of the designs in new limbs for Sophia the Robot.

A Media Frame Analysis of Global Warming Articles Using Natural Language Processing

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Mentor: Anjalie Field, Carnegie Mellon University

Global warming (GW) has recently been viewed as one of the most pressing environmental issues and has been hotly discussed in politics. Growing concerns and controversy over GW has attracted increasing media attention towards this issue. As the media is a major influencer of public opinion, it is important to understand how the media presents or frames GW. This study sought to develop machine learning models for frame detection, identify the best-performing model, and use that model to study how GW is presented in a dataset of ~56K articles. After training a naïve bayes, logistic regression, and BERT model on annotated data, the logistic regression model achieved the highest accuracy (63%) on previously seen issues, while the BERT model achieved the highest accuracy (47%) previously unseen issues. All model performances exceeded the baseline accuracy of 6.67% expected by random classification. Applying the BERT model to the GW dataset revealed temporal framing fluctuations reflective of major events like presidential elections. Further, articles from liberal and conservative outlets exhibited different framing trends, yet the two shared similar dominant frames (i.e. economic, cultural identity, and health and safety). These results can help news sources decide how to cover GW and aid politicians in determining policy agendas. This study also highlights the superiority of deep learning models over traditional algorithms when applied to previously unseen issues, while questioning whether such advantages of deep learning are cost-worthy.

Microplastics Not Shown to Affect Coral Mortality in the Field Like in Laboratory Studies

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Microplastics, an emerging pollutant shorter than 5mm, pose a significant threat as their concentrations increase. With coral reef health in decline, particularly due to rising temperatures, concerns on the effect of microplastics on reef health have arisen. Previous studies investigating this relationship in laboratories have poorly imitated the complexity of field conditions. Therefore, this study explores the effect of microplastics on coral mortality in the field, globally, to better understand this pollutant's threat. By utilizing two databases and filtering data points to those within a 0.2 degree overlap (longitude and latitude), coral mortality, and secondarily, bleaching, were analyzed against the amount of microplastics. Data cleaning was performed to remove invalid or non-quantitative values such as "low" and "severe." Initial analysis revealed that all variables lacked a normal distribution, and various transformations failed to produce a normal curve. Hence, nonparametric statistical tests were used, such as Spearman's Rank Correlation. Mortality data exhibited a

weak positive correlation to microplastics; however, at lower quantities of microplastics, there was a range in coral mortality, while at higher quantities, only high mortality values were present. The same analysis conducted with bleaching data showed no correlation. This suggests microplastics are a factor adversely affecting coral mortality, but not bleaching, in conjunction with other environmental concerns. Hence, these findings do not support that of laboratory studies, which find significant negative effects to coral. This study demonstrates the need for further field research to understand microplastics' role compared to other threats corals face.

SiRNA Based Gene Silencing to Augment Elastogenesis in Abdominal Aortic Aneurysms

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Abdominal aortic aneurysms (AAAs) are expansions of the aorta characterized by enzymatic breakdown of wall elastic fiber structures, causing weakening & fatal rupture. Current management involves periodic image-based growth monitoring with no established drug-based therapies. Reversing disease pathophysiology is difficult as cells are unable to regenerate new elastic fibers. siRNA interferes with gene expression by degrading mRNA after transcription and can be used to stimulate elastic matrix assembly and inhibit proteolytic enzymes (MMP's).

The objective was to determine if gene silencing of EGFR is essential in aneurysmal smooth muscle cells to stimulate regeneration of elastic matrix & inhibit proteolytic enzymes. It was hypothesized that siRNA sequences that inhibit the EGFR gene, can therapeutically reverse elastic matrix aberrations associated with AAAs to regenerate & restore healthy elastic matrix to slow/reverse AAA growth. siRNA effects on MMP expression levels & elastic fiber assembly were studied in in vitro cultures of aortic smooth muscle cells (EaRASMC) from simulated rat models. Four strengths of siRNA were analyzed to identify an optimal concentration that is most effective in inhibiting the EGFR gene. Relative gene expression of EGFR and secondary elastogenesis genes were determined with polymerase chain reaction.

This resulted in improved elastic matrix regeneration through decreases in proteolytic enzyme activity & increases in elastic matrix production and shows the implementation of siRNA based gene silencing to augment elastogenesis can be used as a treatment alternative for AAAs. The study provides an effective, non-invasive, cost efficient reparative solution that can both slow, and reverse elastic matrix aberrations.

NeuroCADR: Drug Repositioning to Reveal Novel Anti-Epileptic Drug Candidates Through an Integrated Computational Approach

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Drug repositioning is an emerging approach for drug discovery involving the reassignment of existing drugs for novel purposes. An alternative to the traditional *de novo* process of drug development, repositioned drugs are faster, cheaper, and less failure prone than drugs developed from traditional methods. Recently, drug repositioning has been performed *in silico* - databases of drugs and chemical information are used to determine interactions between target proteins and drug molecules to identify potential drug candidates. A proposed algorithm is NeuroCADR, a novel approach for drug repositioning via spherical k-means and k-nearest neighbor algorithms (KNN). Data sourced from several databases consisting of interactions between genes, proteins, and drug molecules were compiled into separate binarified datasets. These were inputted into an KNN machine learning algorithm that learned associations between these. The proposed method displayed a high level of accuracy, outperforming nearly all *in silico* approaches. NeuroCADR was performed on epilepsy, a condition

that is characterized by seizures, periods of time with bursts of uncontrolled electrical activity in brain cells. Existing drugs for epilepsy can be ineffective and expensive, revealing a need for new antiepileptic drugs. NeuroCADR identified novel drug candidates for epilepsy that can be further approved through clinical trials. The algorithm was incorporated into a user-friendly website for medical professionals to determine possible drug combinations to prescribe a patient based on a patient's prior medical history. This project examines NeuroCADR, a novel approach to computational drug repositioning capable of revealing potential drug candidates in neurological diseases such as epilepsy.

PUERTO RICO

Adaptation of "Roof Flaps" to Sedan Body Cars to Increase the Probability of Regaining Control at High Speeds

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Speed is a great factor to take into account at the time of an accident, since with only a 1% increase in speed the probability of fatal accidents increases by 4%. For this reason, it is proposed to implement the "Roof flaps" which are a technology introduced in NASCAR, to increase safety during accidents. Can roof flap technology be retrofitted to compact sedans to increase the probability of regaining control at high speeds? If the "Roof Flaps" produce pressure and resistance to the wind, then adapting this technology to sedans will slow down the car and not lift the tires off the ground, increasing the probability of regaining control. An RC was used, which was modified by placing 3 "Roof flaps". To test the effectiveness of these a maneuver was made; Auto Control was set by accelerating and passing to the left of one cone, then at the next cone making a sharp right turn, then another sharp left turn. The procedure was repeated 5 times and 5 times in reverse with each car. The Experimental Auto regained control 0.21s (9.68%) faster and 0.16m (13.56%) sooner on average than the Auto Control. The data shows that the difference in speed between the cars was not significant (0.03m/s, 2.43% slower). The hypothesis was accepted since the Experimental Auto regained control in less time and distance than the Auto Control. It is expected to work with other RC scales such as 1:24 or 1:10 and 3D digitization to adapt it to real cars.

Remote Sensing: Monitoring Droughts and Overexposure to Radiation in Plantain and Vegetable Crops, in the Adjoining Agricultural Fields Between the South of Naranjito and the North of Barranquitas in Puerto Rico

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With the betterment of healthcare and life expectancy, global food demand will increase, and fertile land will be adapted to accommodate a growing population. As a result, agriculture will become an increasingly necessary and laborious process when the repercussions of climate change and fluctuations disturb the growing season. Having a historically agricultural economy in the tropics, Puerto Rico faces heat waves, droughts, prolonged exposure to radiation, and high-impact natural phenomenon. These conditions can limit a harvests' output by negatively impacting crops' growth process and performance. For this reason, this research intends to use Landsat 8 satellite imagery to analyze the greenness, condition, and health of the plantain and vegetable crops found between Naranjito and Barranquitas in Puerto Rico. Thus, it explores the impact that overexposure to radiation and droughts have on some high-demand crops through NDVI, a mathematical representation of plant health based on its reflection of sunlight. Since plants are photosynthetic organisms, they tend to absorb some of the wavelengths of the electromagnetic spectrum, but they emit other bands as well. Hence, QGIS, an open-source software, is used to harness the bands associated with plant health. Additionally, elevations and slopes were studied as decisive variables in the acquisition of minerals and nutrients. Elevated fields, as in Barranquitas, showed abiotic stress indices, while Naranjito, being in decline, had pockets of healthy biomass. Therefore, this

research enables a cost-effective tool that any farmer with a computer and an internet connection can use to monitor their large-scale crops' performance with far-reaching imagery.

The Effectivity of Magnetic Levitation Technology on Improving the Support and Cost-Efficiency of Prosthetics and Assistive Devices

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The World Health Organization estimates that 30 million people around the world are in need of prosthetic and orthotic devices, yet 75% of countries do not have programs set in place to help these individuals (Burt, 2018). *The Effectivity of Magnetic Levitation Technology on Improving the Support and Cost-Efficiency of Prosthetics and Assistive Devices* combats this issue by exploring the subject by building a prototype with inexpensive materials from their local hardware store. Important materials include PVC pipe parts, a plunger cup, a V9 battery, some medium and small magnets, and an electrical cord. The researcher also aimed to utilize the power of magnetic levitation technology by incorporating an arrangement of magnets that would cause the solid body to levitate in midair. The purpose of incorporating magnetic levitation technology to the prototype is to strengthen its base of support, improve stability, cost-efficiency, and weight distribution across the device. The research project also includes a case study with a visually impaired adult male to provide insight for further research, investigate the topic in realistic detail, and understand the problem from the subject's perspective. As there have been no past research projects nor initiatives incorporating magnetic levitation technology into an assistive device with inexpensive materials, this research project is the first of its kind. It is not meant to be complex, but rather set the foundation for more complex projects as a starting base.

Minotaur: A Program with Lego Mindstorms NXT Using C++ to Solve a Maze and Recover an Object

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Mentor: Mr. Gerardo E. Serrano Rodriguez

The researcher will be programming a robot so that it can solve a maze autonomously. The researcher will learn Lego Minestorm NXT (this program uses C++) to program the robot. To solve a maze, it is very important to not give circles because you will never find an exit, this is the reason why my robot will not be employing a single sensor. My robot will be equipped with three sensors, one will be located on the left side, and it will be a distance sensor. The other two sensors will be button sensors, located at the front of the robot. The robot will have a car-like shape, with two chain wheels so that it will be able to give accurate turns by retroceding on one of the wheels. The ideated code will detect an opening to the left, and will always take it, if the wall doesn't have an entrance the robot will encounter a wall eventually on his front, if this happens both tactile sensors will get triggered and the robot will retrocede and give a 180 degrees turn and will proceed to check for entrances on the other wall that used to be on its right side, but now on the left. With this code, based on my analysis, the robot should be able to solve any maze. At the end the researcher found that only one sensing sensor was not enough the robot needs one on both sides to work properly and this will be the future work of the researcher, upgrade the robot to complete the maze and in addition fix the code to also grab an object at the end of the maze and return it to the start.

Luster Regained in Bits and Bytes: A Novel Cyber Incident Risk Prediction Model for Middle and High Schoolers Using Machine Learning

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Physical isolation during the Covid-19 prompted a 45% increase in digital use leading to an increase in cyber incidents. This project seeks to understand the risk impact of prolonged internet use and evaluate opportunities for cyber education to lower such risk. In preparation for subsequent work, the project will learn patterns in distress, and the recovery of affected individuals. A 20-question English-language survey (n= 1,869) was administered to 6th through 12th graders across 4 countries.

Analysis of the survey indicated that the number of hours of internet use was found to be a driver of the risk of cyber incidents. In addition to statistical analysis, the methodology used VertexAI's AutoML to generate an ensemble model to predict risk from usage patterns (length of usage, gaming use etc.). The cyber risk predictor model set has high overall accuracy (f1 score of 0.88) and precision and recall of 0.878. This low-cost approach to personalized risk scores could support periodic evaluation and trending of educational effectiveness in cyber safety. Separately, participants reported a strong association (Spearman rho = 0.957) between distress from cyber incidents and lead time to their recovery. Among the respondents with high distress experiences, there is an urgent need to design support programs to cope with their distress.

SOUTH CAROLINA

Discovery of Potential SARS-CoV-2 Main Protease Inhibitory Compounds from Medicinal Plants

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The novel coronavirus (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has evolved into a global pandemic. Veklury, the sole FDA-approved drug, appears to be limited in terms of efficacy. The purpose of this study was to screen the antiviral activity of extracts from four plants (i.e., Lonicera japonica, Glycyrrhiza glabra, Isatis indigotica, and Scutellaria baicalensis) and to identify potential bioactive compounds against SARS-CoV-2 main protease (3C-like Protease). Butanol and ethyl acetate (EtOAc) fractions of the crude plant extracts on 3C-like Protease assays underwent high throughput screening. The EtOAc fraction of the L. japonica extract displayed significantly higher inhibitory activity on the 3C-like protease compared to all other fractions. Further analysis of the L. japonica EtOAc fraction using liquid chromatography and tandem mass spectrometry with molecular networking revealed five potential compounds as potential inhibitory candidates against SARS-CoV-2 main protease. The compounds of secologanin and luteolin-7-glucoside, based on their cosine scores of over 0.9, were selected as potential drug development compounds for inhibiting COVID-19. Thus, L. japonica could be a potentially promising drug development target for COVID-19.

SARS-CoV-2: A Study of the Dispersion Characteristics of Aerosol Particles Using Ultrafast Carbon Nanotube Sensors in a Simulated Indoor Environment (A Novel Technique)

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The SARS-CoV-2 virus (COVID-19) pandemic has exposed the lack of preparedness of many advanced countries and their methodologies to bring it under control. Understanding the trajectory and spread pattern of virus-carrying airborne respiratory aerosol droplets with quantifiable data can solidify or negate the guidelines for social distancing, and disease control and spread. Carbon nanotubes (CNT) sensors, CSM-eSTEP cough

stimulator, optical particle sizer, and a particle image velocimetry (PIV) were used to a) quantify velocity of exhaled air from cough under normal physiological conditions, b) evaluate and quantify the transport of aerosol particles from a simulated cough and c) assess or evaluate dispersion characteristics of aerosol droplets within the six feet to validate guidelines set by CDC. This experimental trial validated that a cough (teenager and adult) airflow pressure is equivalent to 30-50 PSI compressed airflow from an orifice. The cough airflow trajectory was found to be detectable and quantifiable by sensors as far as 1.3 m (meters) away from the source. Further experimentation revealed a statistically high number (10 cm away, $F(2,87)=4.76$, $p<0.012$, and 1.8 m away, $F(2,87)=4.18$, $p<0.018$) of aerosols particles detected beyond the social distance guideline set by CDC. Lastly, the PIV and velocity vectors reveal the disorderly spread of the aerosol particles thus requiring thorough sanitization in addition to social distancing guidelines. In the future, different indoor criteria of humidity, temperature, and HVAC airflow will be set to understand virus-laden aerosol velocity vectors.

MoJoint: A Motion Visualization and Kinematic Analysis Software for the Musculoskeletal System

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Musculoskeletal disorders (MSDs) affect ~1.7 billion people worldwide. As most MSD cases are associated with abnormal motion of joints, motion assessment of joints provides a powerful tool for the prediction, diagnosis, and treatment of MSDs. However, the present-day diagnosis methods use medical imaging (e.g., MRI), which can only provide static and limited dynamic images. A compelling solution to this challenge is to combine medical imaging with marker-based motion tracking techniques to capture joint motion in an anatomically precise manner. However, the current lack of a user-friendly, open-source software that coordinates the data from medical imaging and motion tracking systems limits the clinical application of this approach. Here, we developed a software (MoJoint) that integrates the geometry files generated from medical imaging and the motion data from a marker-based motion tracking system to calculate joint motion and perform kinematic analyses. To make musculoskeletal kinematic analysis readily available to researchers and clinicians, we developed a graphical user interface (GUI). After completing the first stable version of the software, we used it to assess mandibular kinematics, which is crucial to understanding the cause of highly prevalent temporomandibular joint disorders (TMDs) (affecting ~5-12% of the population) and disparities in TMD risk (including by occlusal class and race). Our data showed that Class II subjects and Caucasians have the highest amount of mandibular translation and rotation in lateral movements, consistent with their high prevalence of TMD. These results demonstrated that our software has a huge potential for improving the prediction, diagnosis, and treatment of MSDs.

A Green Molecular Approach Towards Multifunctional Antifungal Coatings from Plant Oils

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Protective green coatings are advantageous because they are eco-friendly and sustainable. With stringent environmental regulations, there has been a growing interest in utilizing renewable natural resources as candidates for manufacturing eco-friendly coatings (Hermens et al., 2020). The purpose of this study was to advance current protective coatings through a combination of mixed oils. The oils were placed under direct sunlight to form cured films on maple wood. The curing chemistry and its effect on chemical resistance, water resistance and thermal stability were characterized and evaluated by infrared spectroscopy, 13C NMR, solvent immersion, water contact angle and thermogravimetric analysis. It was hypothesized that the unsaturation in the oil chemical compositions would impact their curing ability and fungal inhibition. The oil-coated samples were placed on agar petri dishes that were spread with White-rot fungi. The diameters of growth inhibition for each sample were measured over six days using an Agar diffusion assay. The results from a two-way ANOVA with the replication method showed that the seed oils had a significant effect ($F(6, 588) = 203.0904$; $p < 0.001$).

A post-hoc Tukey test showed significant differences in pairwise comparisons between different oil coatings. By mixing with a small fraction of tung oil, both linseed and soybean oils showed curing rates at least two times faster than individual oils and demonstrated much better inhibition of growth against fungi. This class of green natural seed oil coatings could be beneficial both economically and socially, given their high abundance, low cost, and environmental friendliness.

SOUTHWEST

Optimizing Methods for Analysis of Novel Corona-Virus SARS-CoV-2 Receptor ACE2 Single Nucleotide Polymorphisms

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Mentor, Dr. Veronica Evans, San Juan College, Professor of Biology

SARS-CoV-2 is a quickly evolving world pandemic. To understand this virus better and prepare for future variants, understanding the spike-receptor interactions is important. SARS-CoV-2 attaches to the angiotensin cleaving ACE2 protein. This protein has several known polymorphisms that are suspected to change SARS-CoV-2 binding affinity and thus affect COVID-19 severity. Three common polymorphisms were selected for study and had ligation and PCR primers constructed. A section of the ACE2 gene is amplified through PCR and a ligation is ran on the amplified section to detect if the ACE2 gene had the polymorphism or wild-type sequence. Polymorphisms found in the four corners area population have the potential to help understand how single nucleotide mutations may affect SARS-CoV-2 infections. The materials and machines used are affordable and common, showing that a small lab with motivated undergraduates can obtain this information. Gaining demographic data in a small lab will increase the viability of other small labs to do the same, which will increase the speed of advancements in COVID-19 research. The purpose of this study was to find the optimal conditions for these procedures before human testing begins.

A Habitat Assessment Protocol to Determine Suitability for Southwestern Willow Flycatcher Occupancy in the Northern Rio Grande Watershed

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Mentor: Loree' A. Harvey

The goal of this study is to create a diagnostic "suitability" tool to assess potential habitat for southwestern willow flycatcher (SWFL) sites in the San Luis Valley, Colorado. The tool defined key parameters critical to the life stages of SWFL living in the Upper Rio Grande watershed based on insect forage, habitat structure, and occupancy data collected from known occupied vs unoccupied willow sites. Habitat was assessed with transects to collect height, canopy cover, and leaf gap data. Vegetation coverage was groundtruthed and drawn as polygons using Google Earth Pro. Terrestrial insect forage was sampled from available habitat and analyzed for insect Order and biomass. Habitat and forage characteristics of both occupied and unoccupied sites were statistically analyzed, and significant differences of the parameters defined the "cut score" for each parameter, creating a diagnostic tool by which to measure suitable habitat against poor habitat. The intent is to use this tool to assess other potential Southwestern Willow Flycatcher areas in the upper Rio Grande watershed; both to identify deficiencies and recommend management actions to improve sub-standard habitat based on parameter analysis with the "diagnostic" scoring tool.

Mycro Madness: A Study of the Effect Mycorrhiza has on Solanum tuberosum, Cucurbita pepo, and Medicago sativa When Exposed to Different Environmental Factors

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In 1885 a scientist named Albert Bernhard Frank discovered a fungus that would enhance plants and the amount of offspring they would produce, he coined this fungus mycorrhizae. In this experiment, I grew three different types of plants, russet potatoes, zucchini, and alfalfa, and exposed them to different amounts of mycorrhizae through their growth cycle. I then exposed the plants to different environmental factors that have been occurring more recently due to climate change, these factors being a drought, overwater, and cold. After analyzing my plant height data, I found that mycorrhizae had the most positive effect on the alfalfa plants and the most negative effect on the potato plants. There were significant differences between the control alfalfa plants and the alfalfa treated with double the amount of mycorrhizae in the first two weeks of growth, but after the seventh week, there was no significant difference. There were also significant differences in my drought treatments, both in my alfalfa and squash plants. After analyzing my plant biomass data I found that mycorrhizae had a significant effect on the amount of plant material of alfalfa plants, increasing as the amount of mycorrhizae increased. After analyzing my chloroplast counts I found the mycorrhizae affect almost all plants to a significant level before and after treatment. In conclusion, mycorrhizae has an overall positive effect on plants when looking for a better plant yield, but causes less plant growth and plant material.

Redefining Green Energy with the Power of Chlamydomonas

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With the increase of carbon dioxide within our planet's atmosphere, the temperature on our planet is increasing and at a morbid pace. In addition to the increase of temperatures, there is an increase in population and, eventually, the demand for energy will continue to escalate. The increase of our climate temperature can be attributed to the increase in greenhouse gases from the use of fossil fuels and we just keep harming our planet. Imagine, using green algae as an alternative source of energy, it will help to fight three big problems we face: CO2 emissions, ways to harness renewable sources of energy, and dispose of waste. Many of our current processes to generate hydrogen are very costly and non-environmental friendly. Looking into photosynthetic organisms can be a more cost effective and environmentally safe way. Chlamydomonas are one of many unicellular types of algae, and has over 500 species, with so many options scientists only use a few. The most commonly used species is *Chlamydomonas Reinhardtii*. This is a species of algae that when put under particular situations is capable of mass-producing hydrogen, this is through its own form of photosynthesis. The experimental approach that I am studying is by the depletion of sulfur and addition of copper, on three different types of samples to be gown during the experimental phase. The expected results for the experiment will be to find out which form of algae and process is most useful for the production of hydrogen towards the benefit humanity.

Using Logistic Regression Markov Chain Based Machine Learning Models to Predict Professional Basketball

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Mentor: Daniel Appel, Stevens Institute of Technology

My project is about modeling professional basketball with data science and machine learning. Data science and analytics currently have significant impacts on the NBA's best teams. NBA teams such as the Houston Rockets have used analytics to adopt a unique offensive style. With more research, machine learning and data science could impact major coaching decisions in professional basketball. For this project, I used a Logistic Regression Markov Chain model, or LRMC, as the base for a multi-layered model intended to predict team success. Initially

developed for collegiate basketball, this model uses logistic regression to find elements used to calculate transition probabilities for a Markov chain. The resulting steady-state probabilities can then be used to rank teams in a league or predict the outcome of head-to-head matchups. I formulated design criteria to make the model accurate, practical, accessible, and efficient. I created an LRMC model that met all of these criteria. Using data analysis tools within Python, I was able to make a valuable tool for predicting the outcome of games. From there, I added Monte Carlo simulations to validate the model and simulate across a broader range of teams and more complex scenarios such as playoff series.

TENNESSEE

Red Clover *(Trifolium pratense)* Seedling Responses in Microgravity Simulated by Clinostat – Plant Research in Space

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Mentor: Dr. Alan Forsman
Teacher: Dr. Arpita Nandi

Astronauts started growing various plants that provide nutritional and psychological benefits during their extended stay in the International Space Station. A constant supply of fertilizer is needed to grow food in space. *Trifolium pratense*, more commonly known as red clover is a legume-forming nitrogen-fixing symbiont with rhizobia that can make the growing medium or soil fertile, reducing the use of chemical fertilizer. However, the space environment with altered gravity or microgravity might influence the morphogenesis (growth and development) of red clover. I hypothesize that the growth and development of red clover roots and shoots are modified under microgravity. To test this hypothesis, I used a 2-D clinostat with a horizontal rotational axis at three rotations per minute that simulated a microgravity environment. Using four trials, in an agar medium, I planted seventy-two (72) red clover seeds to compare the growth pattern of the roots and shoots of the seedlings, of which sixty-seven (67) were tested as five seeds did not germinate during the experiment. I placed the samples in a darkroom, supplied light using a grow light for 8 days at a constant humidity (40% RH) and temperature (21.1°C). I measured the root and shoot lengths and curvatures using ImageJ software. The average root length of the experimental and control was 15.58 mm, and 22.29 mm respectively. The average rate of growth (mm/hour) of the root in the experimental and control was 0.08 mm/hour, and 0.12 mm/hour respectively. Root and shoot curvature were measured by the linear distance or depth/actual length; thus, a smaller value indicates tighter curvatures. The roots from the experimental group show altered growth direction, with random and tight curvature compared to the control group; this can be seen through the curvature of the experimental group being 0.56 compared to the control group being 0.79. Similarly, the shoot (the plant stem with its appendages and leaves) experienced similar growing patterns. The average shoot length of the experimental and control was 16.63 mm and 25.24 mm respectively with average shoot rate of growth (mm/hour) of the experimental and control groups being 0.09 mm/hour and 0.13 mm/hour respectively. However, the shoot's curvature in experimental and control groups were 0.68 and 0.67 which indicated that microgravity conditions did not disturb the growing patterns of the shoots. In conclusion, *Trifolium pratense* seedlings experience different growth and development under microgravity conditions.

Planning Equitable Accessibility to Dialysis Care: A Case Study of Hurricane Ida

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In 2021, Hurricane Ida devastated much of New Orleans. Widespread power outages closed numerous dialysis centers (which provide critical medical services for patients with end-stage renal disease (ESRD), forcing patients to seek new facilities and leading to increased travel distance for vulnerable populations. Thus, this research employed the mathematical p-median problem using a set of GIS mapping tools to determine the

optimal reassignment of potential patients to operational facilities before disaster, during disaster, and post-disaster. The results displayed overreliance on a few distinct dialysis centers in New Orleans. Additionally, via cluster analysis, significant increases in travel distance were found to be disproportionate among various demographic groups, highlighting the existence of socio-spatial inequalities in disaster recovery. First, the optimal solutions from the *p*-median problem showed that areas with high populations of residents aged 65+ were significantly more impacted than areas with few residents 65+. Second, though clusters of high and low median incomes did not show notable differences in travel distance increases, high income clusters exhibited much stronger resilience post-disaster. Finally, socio-spatial inequalities along the lines of race were strikingly clear: clusters of Black populations experienced disproportionately greater travel times and demonstrated poor resilience post-disaster. These findings highlight various stresses that individual dialysis centers experience during disasters and underscore which facilities require fortification to mitigate inequalities during disaster recovery. Additionally, the proposed framework of analysis can be utilized to optimize the redistribution of patients to critical locations and combat intrinsic socio-spatial inequalities within any given region.

Stress Response in *C. elegans* – A Biological Model to Assess the Use of Cannabidiol in the Treatment of PTSD

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Teacher: Louis Cowart, Central Magnet School

PTSD affects large portions of vulnerable populations (veterans, assault survivors, etc.), yet the current treatments for this disorder have limited efficacy. Thus, psychiatric research has begun to explore the use of alternative solutions to PTSD, such as medical marijuana. Based on previous studies, there is significant evidence that CBD––the main cannabinoid present in medical marijuana––reduces stress and PTSD related symptoms. Thus, the research observed how CBD modulated the stress response in the model organism *C. elegans* to the anthelmintic Albendazole. Worms were observed at 1µM, 10µM, 100µM, and 1000µM Albendazole, with and without 40uM CBD. Stress responses were analyzed using population multipliers and motility scores, based on the scale developed by Weaver et al. (2017). These values were compared using bar graphs and paired t-tests to determine whether CBD effectively reduced the stress responses in the worms. Results indicated significantly lower stress responses––indicated by higher motility scores––in treatment groups receiving CBD, compared to the groups receiving no CBD.

Neutron Image Reconstruction Algorithms: Parameter Optimization

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Radiography is a non-destructive technique used to visualize the interior of objects using various types of radiation. Radiography is used in fields such as biology, chemistry, engineering, material science, and archeology for samples including fuel cells, engine parts, artifacts, and plants. Neutron imaging utilizes a beam of neutrons to visualize the interior of high contrast, light and fluid materials. Images obtained by neutron imaging have greater contrast as compared to computed tomography (CT) images, but it is a time and cost-intensive process. The raw data obtained from neutron imaging must be reconstructed using algorithms such as the Filtered Back-Projection (FBP) and Model Based Iterative Reconstruction (MBIR). FBP is an analytical reconstruction algorithm that requires images obtained at many angles. MBIR is more time-consuming than FBP, but the resulting reconstructed image is more precise when fewer angles are available. Using samples of bone scaffolding and a meteor, this work optimizes parameter values (number of angles and signal to noise ratio) in each of the reconstruction algorithms. Reconstructing the meteor to a high-quality image using FBP was optimized at 512, the maximum available. However, only 37 angles of the meteor were needed in MBIR to produce a high-quality reconstruction. The optimal snr parameter value for the scaffold using MBIR was determined to be 25 while for the meteor it was 45. These results can be attributed to the sample's elemental makeups.

Inflammatory Impact of Microplastics on Human Lung Cells

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Micro- and nanoplastics are an air- and waterborne pollutant. They are carried globally; high levels have been found in dust in Tehran, snow samples in the Pyrenees, and in ice samples from the Arctic. Textiles pose a commonplace source of airborne microplastics — laundry effluent alone composing an estimated 35% of primary microplastic pollution in the ocean. Clothes also shed fibers into the air through daily wear, leading to a large concentration of indoor microplastics. When the clothes are made of synthetic fiber, plastics are released. Airborne microplastics pose a new threat to human lung health since they can embed in the alveoli and increase the risk of emphysema and cancer. The effect of microplastic particles on human lung epithelial cells was investigated. Based on a literature search of similar studies, it was hypothesized that microplastics would lead to inflammation. Polystyrene spheres of 0.50 µm diameter were added to A549 cell culture media at concentrations ranging from 0.05 µg/mL to 100 µg/mL. Cell counts, a trypan blue viability assay, and photomicroscopy was performed every 24 hours for a 72-hour trial. By 48 hours of exposure, the cells exposed to more than 25 µg/mL of microplastics became visibly more fibroblastic in their appearance. Extracellular vacuoles also appeared, and large masses of cell fragments and adsorbed microparticles formed. It is thus likely that the reaction was inflammatory in nature. These results support the possibility that airborne microplastics pose a potential significant harm to human lung health.

TEXAS

OmniDoc: A Multimodal Quantum Machine Learning Approach to Diagnosis, Prognosis, and Treatment Prediction for Neurodegenerative and Cancerous Diseases

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Despite early diagnosis and estimating the future course of neurodegenerative and cancerous diseases being integral for survival of patients, clinical and algorithmic methods fail to effectively utilize the multimodal data available, are time-inefficient, and expensive, making it difficult to access accurate screenings for these diseases. Therefore, a novel end-to-end quantum machine learning approach using multiple data modalities for the identification of diagnoses, prognoses, and effective treatments is proposed. In a procedural flow, data is sourced from one or more of the following: CT scan images, webcam, patient-physician audio, Whole Slide Images, and clinical data. For image data, a Quantum Convolutional Neural Network, is employed to detect high level features. With text-based clinical data (including audio-derived data), a Bidirectional Encoder Representation model is used to extract text embeddings. For video data, pupil progression and average fixation duration features are manually crafted. All feature vectors are concatenated, normalized, passed through a quantum node, and then mapped to one of 38 neurodegenerative and cancerous diseases. For prognosis, features are pooled, concatenated with the diagnosis feature vector, and passed through another quantum neural network with an output of survival times. Treatment prediction involves an information-retrieval task matching feature vectors to treatments/drug lists from the FDA. The proposed approach was tested on 5,000 patient profiles sourced from the public TCGA and JPND databases, outperforming all other state-of-the-art approaches. The model predicted diagnoses with an accuracy of 98.53%, achieved a Concordance Index of 0.94 in predicting prognoses, and in treatment prediction achieved a 99.32% accuracy.

Scalable and Sustainable Synthesis of a Novel, Bio-Based Polyurethane Foam System Incorporating Industrial Byproducts and Waste

Sohi Patel
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Sponsor: Dr. Sara Fox

Polyurethane foam, a material valued across countless industries for its high performance and versatility, is composed of hazardous, nonrenewable petrochemicals that continuously off-gas into the atmosphere, threatening the environment. These chemicals are synthesized using complex, inefficient methods that involve excessive reagents and costly energy expenditures. In response, two novel biochemicals were developed for sustainable polyurethane foam: a biopolyol was synthesized through cellulose liquefaction, and Wohl-Ziegler bromination of triglycerides and subsequent isocyanate group substitution yielded a bio-isocyanate. Scalability and sustainability were promoted throughout synthesis by chemical recovery and regeneration, minimal reagent use and loss, and incorporation of prolific industrial byproducts and waste. Substantiated by metrics of green chemistry, synthesis routes and chemical compositions were found to be highly economically efficient (Avg Atom Econ: 84.25%; Avg Rxn Eff: 126.35%). Developed biochemicals were then tested with each other and with corresponding petrochemicals to synthesize three partially or fully bio-based polyurethane foam systems. Material performance was measured for each foam: two of three, including the fully bio-based system, performed similarly to standard foam ($p = 0.59$; $p = 0.14$), suggesting high functionality. Environmental safety was also measured: all three bio-foams exhibited superior safety characteristics when compared to standard foam (ALL: $p < 0.001$). Of all samples developed, the fully bio-based polyurethane foam system demonstrated optimal properties; this rigid, non-emitting material may best be applied in construction, boasting the world's first scalable, sustainable polyurethane foam synthesis method and composition.

ParkinSensor: Computer Vision and Ensemble Machine Learning-Based Incipient Diagnosis for Parkinson's Disease Using Neuromuscular Biomarkers

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Teacher: Ms. Baker

Parkinson's disease (PD) is a neurodegenerative disorder that affects 10 million people worldwide. Current diagnostic measures consist of ambiguous surveys or are extremely invasive, and incipient diagnosis is not clinically implemented. As a result, 1 in 4 patients is misdiagnosed, which can lead to worsening of the disease. The Parkinsensor is a noninvasive device that performs an accurate diagnosis for PD patients based on machine learning analysis of neuromuscular biomarkers, specifically eye blinking patterns and voice analysis. In order to optimize a machine learning (ML) algorithm to perform a diagnosis based on voice patterns, 3 ensemble ML algorithms were trained with 435 Parkinson's voice samples and 773 control samples from the UC-Irvine Database. All methods yielded a high accuracy rate for identifying PD data versus control data, with the Random Forest algorithm having the highest percentage at 98.7%. In order to perform a diagnosis based on eye blinking, a training set of 56 Parkinson's eye movement videos and 85 control videos were used. Haar cascades, histogram of oriented gradients, and support vector machine techniques were used for computer vision and feature extraction. Using this data, the device's algorithm was able to identify 98.6% of testing subjects correctly. The accuracy rates for this device's neuromuscular-based method outperformed current clinical methods by over 25%, indicating the effectiveness of ML techniques for PD diagnosis. The device can be used in a clinical setting to prevent patient misdiagnosis, which revolutionizes neurodegenerative disorder diagnostic processes by providing a non-invasive, low-cost solution for incipient diagnosis.

A Third Year Study on the Bioremediation of Tetracycline Polluted Soils: How Antibiotic Resistance Can Reduce Antibiotic Pollution in the Environment and a Solution to Antibiotic Pollution-Related Crop Failure

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Teacher: Ms. Julie Baker, Plano East Senior High School

Antibiotic pollution in soils and groundwater is one of the world's most pressing problems. There are 1.4 µg of antibiotics per-liter of freshwater and 125,000 tons of antibiotics polluted every year from humans and livestock usage. These antibiotics hinder crop growth, exacerbate antibiotic resistance, and pollute groundwater. However, no commercial treatments to degrade antibiotics in the environment exist. This project offers 1) a novel, natural approach to detoxifying antibiotic pollutants by utilizing antioxidants and bacterial enzymes produced by antibiotic resistant bacteria and 2) justification for implementing these solutions into the environment by testing them in vivo in wheat and corn. It was hypothesized that the ascorbic acid soil treatment would yield the greatest rate of crop growth in a model antibiotic polluted environment. Antioxidants – ascorbic acid, beta carotene, and glutathione – and bacterial enzymes – chloramphenicol acetyltransferase, beta lactamase, and *E.coli* nitroreductase – were used as catalysts in bioremediating tetracycline (the most prevalent antibiotic pollutant) polluted soils, along with untreated tetracycline polluted soil as a control group. Antibiotic degradation and crop health were determined by crop height, rate-of-growth, and chlorophyll absorbance, as tetracycline inhibits protein synthesis and photosynthesis. The hypothesis was refuted: chloramphenicol acetyltransferase (4.98cm/4days) and *E.coli* nitroreductase (5.49cm/4days) had the highest growth rate for corn and wheat, respectively. Additionally, all treatments' efficacies were corroborated as all crops grown in treated soils yielded chlorophyll absorbance higher than those of the control. Data was statistically significant through ANOVA tests. Thus, this project yields a promising solution for antibiotic pollution in the environment that is not only effective, but environmentally feasible and friendly.

VIRGINIA

An Optimized Whitewater Helmet Prototype Designed Using a Newly Developed Helmet STAR Evaluation System and 3D Printing

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Teacher/Sponsor: Katharine Davis, Blacksburg High School
Mentor: Mark Begonia, Virginia Tech

Whitewater sports result in 50 deaths and thousands of concussions every year, and the currently available helmets are insufficient. The objective of this study was to create an optimized whitewater helmet prototype designed using the newly developed Whitewater Helmet STAR Evaluation System and 3D Printing. The 21 helmet models that were evaluated using the Whitewater STAR methodology were cut vertically and horizontally to allow for cross sectional padding analysis. A material testing system (MTS) was used to evaluate each helmet's padding stiffnesses. The padding Vinyl Nitrile (VN) 600 and VN 740 were found to have the greatest correlation with the highest performing helmets through linear regression and energy absorption analysis. Rhino 3D software was utilized to create the new model of the whitewater helmet. The helmet shell was developed as a modified ellipsoid with a length of 28.5 cm and a height of 13.0 cm above the midline. Three different materials of Accura 60, Nylon, and Accura ClearVue were selected for the helmet shell in order to test a variety of material properties. Using these materials, three different prototypes were constructed in order to optimize the padding and retention of the helmet design. A custom pendulum impactor device was used to test the three different helmet prototypes in accordance with Whitewater STAR. The prototypes were impacted at 3.1 m/s and 4.9 m/s to the front, side, and rear. The final prototype produced a STAR value of 0.01 and performed 25 times better than the best currently available whitewater helmet.

The Effects of Bycatch Reduction Devices on Crab Catch Rate

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Teacher: Dr. Kevin Goff, CBGS

The native population of diamondback terrapins *(Malaclemys terrapin)* has been on a steady decline throughout the past century on the East and Gulf Coasts. Currently, their numbers are being decimated by the blue crab *(Callinectes sapidus)* fishery. The crab pots employed in this industry catch not only large quantities of blue crabs, but also the diamondback terrapins, which then drown in the pots. Recently, scientists have come up with a solution that will exclude the diamondback terrapins from entering the crab pots while still allowing the blue crabs to enter. These devices are called bycatch reduction devices (BRDs) and the purpose of this study was to test the effects that they have on the number and size of blue crabs caught in their pots. Ten crab pots were deployed randomly, five containing BRDs and five without BRDs, in two parallel lines. At the halfway mark in the study, the two lines of pots were switched. Crab catch rate for each crab pot and carapace lengths of each crab were measured every two to three days for a total of two weeks. This study found that while the BRDs do not affect the size of crabs caught, they do negatively affect the number of crabs that outfitted pots are able to catch, perhaps due in part to increased algae growth on the devices themselves.

Phish: A Novel Hyper-Optimizable Activation Function

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Sponsor: Dana Delano, Godwin High School

Deep-learning models estimate values using backpropagation. The activation function within hidden layers is a critical component to minimizing loss in deep neural-networks. Rectified Linear (ReLU) has been the dominant activation function for the past decade. Swish and Mish are newer activation functions that have shown to yield better results than ReLU given specific circumstances. Phish is a robust non-monotonic activation function proposed here. It is a composite function defined as f(x) = xTanH(GELU(x)), where no discontinuities are apparent in the differentiated graph on the domain observed. Generalized networks were constructed using different activation functions. SoftMax was the output function. Using images from heterogeneous medical imaging databanks, these networks were trained to minimize sparse categorical crossentropy. A large-scale cross-validation was simulated using stochastic Markov chains to account for the law of large numbers for the probability values. Statistical tests support the research hypothesis stating Phish could outperform other activation functions in image classification. In a first of its kind, Phish hybridizes Identity, Hyperbolic, and Gaussian mathematical relationships to create a unique transformation profile using continuity, non-monotonicity, and differentiability. When used disease classification models, the core math engine identified Coronavirus, Tuberculosis, Carcinoma, and Pneumonia from 96-99% accuracy. The models were also adept at identifying subtypes and malignancy of lung cancer in addition to viral and bacterial chest infections. The next generation activation function provides state-of-the-art training dynamics for expediting subvariants of stochastic gradient descent backpropagation. Future experiments could involve using Phish in generative adversarial networks training in an unsupervised two-player minimax framework.

Examining the Effect of *Schistosoma mansoni* on the Development of Peanut Allergy using a Periplaneta americana Model

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Mentor: Dr. Johanna T. Cannon, Academies of Loudoun

Peanut allergy is one of the most common food allergies in the world; however, despite the substantial amount of research conducted on the topic, the root cause of this disease remains unknown. Prior research has established that Ara-h-1, a major peanut antigen, is cross-reactive with the highly immunogenic proteins

IPSE/*a*-1 and *k*-5, secreted by the eggs of the parasitic blood fluke *Schistosoma mansoni*. Here, we propose that this cross-reactivity contributes to the development of some peanut allergy cases. We investigated a positive correlation between *S. mansoni* and peanut allergy using *Periplaneta americana* as our model organism, since these cockroaches are capable of mounting a humoral immune response comparable to that of humans. This research consists of two phases: a behavioral study followed by a study to evaluate its findings at a molecular level. After conducting the behavioral study, we established that cockroaches injected with a soluble *S. mansoni* egg antigen exhibited physical symptoms of an allergic reaction after consuming peanuts, likely due to the aforementioned cross-reactivity. This study demonstrated a novel association between a parasitic worm and food allergy in vivo. We are currently in the process of conducting a Western Blot with antibody-like molecules collected from cockroaches involved in the behavioral study. The results of our research could potentially change the scientific community's views on peanut allergy, as well as other food allergies, and lead to new lines of inquiry with the hope of finding a cure.

FluVaxAI: A Novel AI Inspired Regional Flu Vaccine Formulation

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Influenza virus causes an estimated 9.0-35.6 million severe illnesses and 850,000 deaths worldwide annually. Aided by its error-prone, open-ended RNA genome, the virus mutates rampantly to evade the host immune system. The annual quadrivalent flu vaccine has two components each of Type A and Type B lineages. Type A strains cause majority of the flu related morbidity and mortality because they have zoonotic hosts. WHO/CDC announce a single global flu vaccine annually. This one-vaccine-fits-all-worldwide model has limited effectiveness (mean: 40%, range: 10%-60%). In this experiment, the global and regional vaccines were the levels of independent variable. Efficacy of the vaccine was the dependent variable. It was hypothesized that the vaccines tailored to the regions around the globe would be more effective. FluVaxAI presented here is a novel methodology for computing antiviral vaccines. Nucleotide and protein sequences of the hemagglutinin segments of the influenza virus were downloaded from the IVR and GISRIS data repositories. Mutations in individual amino acids in the segments were tracked over the study period of 2005 to 2020. A long short-term memory model was fitted to the mutational history of the amino acids to project their future course. The vaccines were then assembled from the resulting amino acids. The process was repeated for each region. The computed regional vaccines were distinct and showed efficacy in their respective regions, proving the hypothesis. The results for Africa and Asia need further investigation. The future work could include refinement of the model and field testing. There were no safety issues.

VIRTUAL

Using Deep Learning to Estimate Greenhouse Gas Emissions Via Satellite Imagery

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Greenhouse gasses (GHG) emitted from fossil-fuel-burning power plants pose a global threat to public health, causing 8.7 million deaths per year through air pollution and raising the frequency of natural disasters. Quantifying GHG emissions is crucial for the success of future climate action. However, current methods to track emissions cost upwards of $520,000 per power plant. These methods are cost prohibitive for developing countries, and are not globally standardized, leading to inaccurate estimations in emissions reports from nations and companies. I developed a novel, low-cost solution via a end-to-end deep learning pipeline that utilizes observations of emitted smoke plumes in satellite imagery to provide an accurate, precise system for quantifying GHG emissions at an global scale by 1) segmentation of power plant smoke plumes 2) classification of the type of fired fuel 3) algorithmic prediction of power plant CO2 emissions. The pipeline was able to achieve a segmentation Intersection Over Union (IoU) score of 0.924, fuel classification accuracy of 96%, and quantify

power generation and CO2 emission rates with a R-Squared (R^2) value of .91 and a Mass Absolute Error (MAE) within 6.3%, indicating high performance across global regions. The results of this work are significant because they enable the identification of major sources of GHG emissions and their temporal monitoring on a global scale at a low-cost. This enables the development of more-effective climate policy and transparency regarding compliance with the Paris Climate Agreement and COP26 goals, revolutionizing the way we tackle climate change.

The Search for Dark Matter Through Soft Unclustered Energy Patterns at CMS

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Soft unclustered energy patterns (SUEPs) have signatures of spherically symmetric, high multiplicity showers of low-energy particles. Despite being a potential candidate for dark matter, SUEPs have remained unexplored as these events resemble pileup and are recorded with traditional triggers with very low efficiency. Here, strategies are developed for the Compact Muon Solenoid (CMS) particle detector to separate SUEP candidates from the quantum chromodynamics (QCD) background by investigating Monte Carlo simulations of SUEP and background events. The FastJet algorithm clusters tracks to form SUEP candidates for analysis. The discriminatory power of our variable selection, which is measured through σexp/σtheory, is tested before and after boosting into the SUEP candidate frame for several different heavy scalar mediator masses. At S = 400 GeV, the selection on the boosted FW2M variable (σexp/σtheory = 0.17578) marginally surpasses in discrimination than other boosted jet shape variables such as sphericity (σexp/σtheory = 0.18066) and aplanarity (σexp/σtheory = 0.18555). At higher mass benchmarks (S ≥ 750 GeV), SUEP candidates are fully separated from the background for all selections (σexp/σtheory σ 1). Thus, boosting is a necessary approach for discriminating SUEP candidates, especially for low mass scalar mediators with S ≤ 400 GeV.

Cyclo.Plas 2: A Dual Focus Development as Alternative Materials to Plastic by Upcycling Fish Scale Waste Components

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Teacher: Kirstin Olson, PLTW Biomedical Science, Mountain House High School

The COVID-19 pandemic has exacerbated plastic pollution with the rise in PPE and single-use plastic consumption amplifying our plastic dependence and adding more plastic to our oversaturated oceans. Using biomimicry of the fish scale composition, calcium salts and collagen, my goal is a dual-focus materials development addressing the lack of plastic degradability and waste accumulation.
Focus 1 applied the biomineralization concept to valorize 3D-printed PLA waste with fish scale-inspired minerals/hydroxyapatite to form a composite. Focus 2 utilized the sclerotization concept to enhance the physicochemical properties of intact collagenous matrix of fish scale waste, to form a thin, plastic-like material. Each focus had three parts: synthesis/formation, physical testing, and degradation/environmental testing.
As composites, flexural strength exceeded that of 3D-printed PLA waste, and had higher degradation rates in hydrolysis, home composting, and acidic environments. Hydroxyapatite reinforces the structure and improves degradation, supported by SEM observations. As thin films, tensile strengths were comparable to LDPE, with 86% transparency and high shrinkage performance in 140-150°C, where LDPE melts. Samples biodegraded in soil after 8 weeks with no phytotoxicity and 3-7% higher plant growth. Trials showed improved thermal stability and water resistancy, yet could degrade with low total dissolved solids.
The results supported the hypothesis that synthesis with fish scale waste components is key to the strength and degradability of Cyclo.Plas_2. The cost-effective prototypes are targeting single-use items and viable as non-medical PPE. Cylo.Plas_2 serves as a preventative solution and practical disposal solution through home composting to promote a circular economy.

Spira Aer: A Novel Hurricane-Inspired Logarithmic Spiral Fan Design for HVAC System Applications

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Heating, cooling, and ventilation consume $122 billion/year in the US. Improving the systems' efficiency, even just slightly, will lead to significant cost savings. The goal is to develop high-efficiency fans for ventilation and HVAC systems, implementing the logarithmic spiral, called Spira Aer.
Spira Aer was developed in 3 phases, each including designing in Solidworks, 3D-printing, testing, analyzing data in Excel and Solidworks Flow Simulations, and elimination/improvement processes. Design criteria were set for the fan design, motor interface, duct system, and the overall system, to discover how each design element affects performance, to create efficient and repeatable test processes, and to approximate real-world conditions. Pressure, airflow, RPM, and efficiency were measured to analyze the performance.

Lower tip angles cut into the air more efficiently, enabling it to harvest more air in its sweep area, and reduces the fan's mass. Lower blade revolutions produce higher pressure, but higher revolutions generate higher airflow. Center passive areas reduce circular airflow, allowing more energy to be converted to lateral airflow, increasing efficiency. 18-Blade balances the surface/mass ratio, maximizing efficiency.

The results supported the hypothesis, Spira Aer achieved higher pressure and efficiency than the propeller fan, with comparable airflow, and higher airflow than the centrifugal fan. Spira Aer performs best in medium-low system resistances with high airflow, can save 30-50% of costs in applications like cooling electrical equipment, heat exchangers, forced ventilation systems, and whole-house ventilation. It can easily replace existing propeller fans using a simple adaptor, keeping the same motor and frame design.

From Food Waste to Food Guard: Creating A Novel Chitosan Bioplastic Using Nanoparticle Coating and Its Unique Effect on Food Packaging and Preservation

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Mentor: Mark Hiza

Plastics, despite their benefits in transforming our lives in multiple aspects, have caused serious environmental and aquatic pollution. The objective of this project is to create low-cost, sustainable chitosan bioplastic, explore its unique antimicrobial application in food preservation, and design a novel approach to solve the water permeability challenge.

Chitosan, the second most abundant polymer made from shells of shellfish, is selected as the base material. Development process includes heating, molding, drying/cooling to create chitosan bioplastic films.

Second, chitosan bioplastic was evaluated against conventional plastics on tensile strength, water permeability, and water/soil degradability. Results showed that chitosan bioplastic can sustain similar tensile strength as conventional plastics, but possess distinctive environmental advantages in water dissolution under a week and soil degradation within 90-days.

Third, to explore chitosan's antimicrobial application, it was discovered through repeated tests that chitosan bioplastic created from this project could prolong perishable fruits' shelf-life by five times compared with conventional plastic, generating unique economic values in food preservation.

Lastly, to solve the water permeability challenge, silicon dioxide nanoparticle coating was created to apply to chitosan bioplastic films using Langmuir-Blodgett technique, which improved its water-resistance by raising the water contact angle from 40-60 up to 124-degrees.

Chitosan bioplastic created from this project has proved to be a next-gen low-cost and eco-friendly alternative to conventional plastics. In addition, the unique antimicrobial application in food preservation and significant improvement in water resistance through nanoparticle coating have made chitosan bioplastic a unique and highly viable bioplastic option for food packaging and preservation.

WASHINGTON

A Comparison of Machine Learning Algorithms in Identifying Higgs Boson Events from the Background

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Mentor: Dr. Savannah Thais, Princeton

Since its detection in the Large Hadron Collider (LHC) in 2012, the Higgs boson has remained a key element in confirming the standard model (SM) of particle physics. Current research to find Higgs boson decay channels predicted by the SM requires being able to accurately identify Higgs bosons or signal events from a noisy background. Through use of machine learning, signal events can be accurately classified in offline reconstruction; however, there exist many classification models which might suit this purpose. This study compares three supervised classification models in their ability to accurately and efficiently identify signal events: boosted decision trees, support vector machine, and neural networks. With an accuracy of 83.88%, F1-score of 81.72% and a training time of 8.4 seconds using the simulated dataset from the 2014 ATLAS Higgs boson Machine Learning Challenge, a histogram gradient boosted decision tree was determined to be the most effective classification model for identifying Higgs boson events. The worst performing algorithm was the support vector machine with the lowest accuracy at 80.35%, F1-score of 77.12%, and the second lowest training time of 50 minutes.

Identification of Co-Expressed Genes to BDNF and trk-B as Major Depressive Disorder Related Biomarkers Using Microarray Data

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Teacher Kate Allender, Nikola Tesla STEM High School

Depression is a leading cause of death and disability with more than 264 million people of all ages suffering from the disorder worldwide. Understanding how brain function is altered in depressed patients is crucial for determining novel biological targets that can be used to prevent suicidal behavior. This project aims to identify potential biomarkers for major depressive disorder by finding co-expressed genes with brain-derived neurotrophic factor (BDNF) and receptor tyrosine kinase B (trk-B), two genes that contribute to the pathophysiology of depression through neuron growth and survival (neuroplasticity). 3055 probes for genes involved in nervous system development were screened from public microarray data in the Allen Human Brain Atlas. Average gene expression level and Pearsons correlation coefficient were calculated for each probe using Java programming and Excel to determine correlations between either BDNF or trk-B and a potential gene biomarker. A total of 93 and 27 coexpressed genes were identified for trk-B and BDNF respectively with a significant Pearsons correlation of above +0.5 (trk-B: 0.82>x>0.50, BDNF: 0.68>x>0.50). In addition, 72 biomarkers were further identified by gene function and trends in data as especially important to depression research. These biomarkers may provide new insight into genetic factors for vulnerability to depression involving brain neuroplasticity and can be used to create new therapies as drug targets or to improve the remission rates of existing therapies.

Elucidating the Mechanisms of Drug-Induced Hearing Loss: Characterization of Interferon Gamma Signaling as a Novel Regulator of Inflammation and Hair Cell Regeneration in Zebrafish

Rohak Jain

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Mentor: Shuyi Ma (Assistant Professor, Seattle Children's Research Institute)

As a common side-effect of aminoglycoside antibiotics and cancer-related medications, drug-induced hearing loss (ototoxicity) can severely deplete inner ear hair cells and cause long-term sensorineural hearing damage as a result, especially considering that there are currently no USFDA-approved drugs specifically designed for this disorder. Although signaling pathways like FGF, Jak-Stat, and Notch have been well-characterized in the context of ototoxicity, Interferon Gamma signaling remains largely unexplored, only being looked at through the lens of inner ear antigens and inflammation-mediated cochlear injury. To elucidate the regulatory role of IFN-Gamma, Differential Gene Correlation Analysis revealed that heat shock proteins, activators of microglia, and a host of pro-inflammatory cytokines were differentially co-expressed with Interferon Gamma to a statistically significant degree, suggesting that IFN-Gamma is likely involved in regulating response to stress and environmental stimuli immediately after ototoxin exposure. Additionally, Weighted Gene Co-Expression Network Analysis indicated that Interferon Gamma and its broader co-expression network were significantly more correlated with the 1-Hour timepoint post-treatment than they were in the 3- and 5-Hour Timepoints across both cell types. Downstream gene ontology analyses demonstrated cell-dependent mechanisms of Interferon Gamma - while its co-expression network for the support cells was strongly correlated with p38-MAPK signaling and selenium metabolism, ubiquitin-protease and T-Cell Receptor Activity were enriched for the mantle cells. By providing some of the first insights into the functional groups associated with the regulatory and inflammatory response of Interferon Gamma to ototoxic drug, this study has significant long-term implications for the development of more clinically efficacious otoprotective pharmaceuticals.

Predicting Nitrogen Isotope Fractionation in Nitrate Deposition on Early Mars

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Mentors: Danica Adams, California Institute of Technology; Michael L. Wong, Carnegie Institute for Science; Kayla Smith, Central State University; Yuk L. Yung, NASA Jet Propulsion Laboratory

The habitability of early Mars was majorly impacted by nitrogen, which has undergone loss to space over time. Knowledge of nitrate deposition is valuable since it gives additional insight into the question of ancient Mars' habitability. Nitrogen's isotopic ratio can be used to constrain total N2's escape. Two formation processes and corresponding ages are currently debated. Nitrates were deposited on the surface, either via lightning-induced fixation in an early warm climate or reactions over longer timescales in a cold climate. These nitrates record fractionation imparted by planetary processes at the time of formation. If observed by future scientific missions to Mars, predicting fractionation caused by these two processes will help to constrain the contribution of each formation mechanism. Processes influenced by the loss of Mars' magnetic field including photochemistry are responsible for the loss of the atmospheric nitrogen reservoir to space (~4.0-3.7 Ga). We use the Caltech/NASA JPL 1D photochemical model, KINETICS, to conduct simulations of early and modern Mars with a primordial 15N/14N ratio. Near the surface of early Mars, where deposition occurs, the 15N/14N ratio in NOy species is slightly less than the primordial ratio. In the upper atmosphere, NOy species form via SEP events, so their ratio in the upper atmosphere decreases by 3.3% to match the primordial ratio scaled by the ionization potential. The dichotomy between the isotopic ratio in NOy and N2 is greater in the simulated modern atmosphere, especially in the lower atmosphere as lightning is no longer a means of formation.

Inferring the Neutron Star Maximum Mass and Lower Mass Gap in Neutron Star—Black Hole Systems with Spin

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Gravitational-wave (GW) detections of merging neutron star-black hole (NSBH) systems probe astrophysical neutron star (NS) and black hole (BH) mass distributions, especially at the transition between NS and BH masses. Of particular interest are the maximum NS mass, minimum BH mass, and potential mass gap between them. While previous GW population analyses assumed all NSs obey the same maximum mass, if rapidly spinning NSs exist, they can extend to larger maximum masses than nonspinning NSs. In fact, several authors have proposed that the ⊙2.6M⊙ object in the event GW190814 -- either the most massive NS or least massive BH observed to date -- is a rapidly spinning NS. We therefore infer the NSBH mass distribution jointly with the NS spin distribution, modeling the NS maximum mass as a function of spin. Using 4 LIGO-Virgo NSBH events including GW190814, if we assume that the NS spin distribution is uniformly distributed up to the maximum (breakup) spin, we infer the maximum non-spinning NS mass is 2.7+0.5−0.4M⊙ (90\% credibility), while assuming only nonspinning NSs, the NS maximum mass must be >2.53M⊙ (90\% credibility). The data support the mass gap's existence, with a minimum BH mass at 5.4+0.7−1.0M⊙. With future observations, under simplified assumptions, 150 NSBH events may constrain the maximum nonspinning NS mass to ±0.02M⊙, and we may even measure the relation between the NS spin and maximum mass entirely from GW data. If rapidly rotating NSs exist, their spins and masses must be modeled simultaneously to avoid biasing the NS maximum mass.

West Virginia

Yellow to Green: Low-Touch Route Optimizations to Reduce the Carbon Footprint of School Buses

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Teacher: Mr. Gibson, Morgantown High

The transportation sector is the largest source of greenhouse gas emissions, making up 29% of US emissions with school buses as a significant contributor. While switching to electric buses may be on the horizon, the transition is expensive and not currently feasible for most public school districts. This study proposes a zero-cost solution to reduce the environmental impact of the Monongalia County Schools' bus system through route optimization. The study focused on one particular high school (Morgantown High) in Monongalia County since it encompassed the largest geographical area and over three times as many buses as other local high schools. Data was collected from the county website where official publications of bus stops, times, and routes were posted. The routes were optimized using the Google Maps API (Application Programming Interface), which calculated the most efficient routes from bus stop GPS coordinates among other variables. The optimization resulted in the saving of a total of 76.4 miles per day and 139.2 minutes for this singular school. Annually, these reductions would save $7,660 on fuel alone (based on current fuel prices) and prevent 20 metric tons of CO2 from being emitted into the atmosphere. A web-based platform was developed to make this process more accessible to other schools. Given any list of bus stop addresses, the site will automatically optimize and compare route distances and durations; it calculates the fuel and carbon emission savings from adopting the optimized route. The new stop (waypoint) ordering and route are also provided.

WISCONSIN & UPPER MICHIGAN

Survey of Mississippi River Unionids for Viruses Associated with a Mortality Event in the Clinch River

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Mentor: Eric Leis, U.S. Fish and Wildlife Service

Advisor: Julie Lundeen

Many mussel populations in North America and other parts of the world have seen catastrophic declines and

mass mortality events, raising concerns about what this trend may mean for aquatic environments. Mussels provide invaluable services to the ecosystem, from water filtration to water quality indication to food web enhancement. Their shells provide habitats and nesting sites for small fish and insects. In the past, unionid population declines have been attributed to pollution, habitat degradation and the introduction of exotic species with little consideration given to the role of disease until recently. The cause of these declines remains enigmatic, however a link was discovered between cases of mortality and a novel densovirus (hereafter referred to as *Clinch densovirus 1*). The purpose of this study was to determine the prevalence of this densovirus and several other viruses (Clinch CRESS virus 1, *Clinch picorna-like virus 1*) among mussels in the Mississippi river. Samples from 59 mussels of various species and location were collected, and hemolymph samples were taken from their anterior adductor muscles. A subset of 30 samples was chosen for analysis. Samples were analyzed via recently developed qPCR assays, and results indicated that two Pocketbooks *(Lampsilis cardium)* tested positive for Clinch picorna-like virus 1. One Wabash pigtoe *(Fusconaia flava)* was positive for both *Clinch picorna-like virus 1* and *Clinch densovirus 1*. Further study is necessary to confirm they are indeed the same viruses, but results may indicate a range and host expansion for the viruses, which could have implications for mussel populations in the Mississippi river. The assays evaluated in this study could be used to survey different geographic regions, to evaluate mortality events, and to study how much the virus replicates in experimental studies.

Impact of Dietary Consumer Behavior on Non-alcoholic Fatty Liver Disease Vary by Socioeconomic Status

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Non-alcoholic fatty liver disease (NAFLD) affects 25% of adults, becoming the most prevalent cause of liver disease in the world. Although socioeconomic factors are known to have an effect on NAFLD, the effects of food spending and dietary consumer behavior on NAFLD are unclear. This study aims to evaluate the impact of food spending and dietary consumer behavior on NAFLD. The study used data from the National Health and Nutrition Examination Survey (NHANES) 2017 to 2018, including FibroScan, diet, and consumer behavior data. Participants (n=3486) were categorized into no NAFLD, NAFLD without advanced fibrosis, and NAFLD with advanced fibrosis based on Fibroscan. High- and low-income groups were distinguished using self-reported family monthly income and poverty index. A multivariable ordered regression model was conducted. The results showed that frequent fast food consumption was associated with more severe NAFLD in high-income(HI) groups, while more frequent home preparation of meals and greater proportion of money spent on groceries protected against NAFLD in HI groups. These findings were not found in low-income(LI) groups. HI groups have better diet quality, particularly in those who prepare meals at home more frequently. These findings indicate that dietary consumer behaviors–such as fast food consumption and home preparation of meals–are independently associated with NAFLD, but this may be affected by economic status. Thus, lifestyle interventions for NAFLD should consider patients' dietary behavior, such as fast food consumption and home preparation of meals, but should consider diet quality which is likely affected by the individual's socioeconomic status.

Developing an Associative Network Model Method to Elicit Tip-of-the-Tongue Syndrome for Clinical Use in Memory Disorders

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Mentor: Dr. Jonathan Flombaum, Johns Hopkins University

Tip-of-the-Tongue (ToT) syndrome has been studied in metacognitive and clinical research for the purpose of understanding its implications on conditions such as Parkinson's disease, aphasia, and multiple sclerosis. ToT occurs when one cannot remember a certain word but can recall words of similar form or can recall the first few letters of the word. This study aims to not only develop a new, efficient method using an associative network

model that can be used in clinics and laboratories to elicit ToT in subjects but additionally discover if ToT is mostly characterized by partial or abstract-form recall, both different types of recall one can experience with ToT. All participants had no known memory conditions. In this study, participants had an audio recording of a short list of words and their definitions played to them. The participants' main job was to remember the words to the best of their ability. Once this was over, they were asked a series of questions that would then determine whether they experienced ToT and which type of recall. Overall, not only was the method more efficient than methods used in past ToT research, but the results revealed that ToT was mainly characterized by partial recall.

Efficient Cauchy Distribution Based Quantum State Preparation by Using the Comparison Algorithm

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Teacher: Jeff Patterson, Homestead High School

The quantum Monte Carlo algorithm can provide significant speedup as compared to its classical counterpart. So far, most reported works utilize Grover's state preparation algorithm. However, this algorithm relies on costly controlled Y rotations to apply the correct amplitudes onto the superposition states. Recently, a comparison-based state preparation method was proposed to reduce computational complexity by avoiding rotation operations. One critical aspect of this method is the generation of the comparison threshold associated with the amplitude of the quantum superposition states. The direct computation of the comparison threshold is often very costly. An alternative is to estimate the threshold with a Taylor approximation. However, Taylor approximations do not work well with heavy-tailed distribution functions like the Cauchy distribution which is widely used in applications such as financial modeling. Therefore, a new state preparation method needs to be developed. In this study, an efficient comparison-based state preparation method is proposed for the heavy-tailed Cauchy distribution. Instead of a single Taylor approximation for the entire function domain, this study uses quantum piecewise arithmetic to increase accuracy and reduce computational cost. The proposed piecewise function is in the simplest form to estimate the comparison threshold associated with the amplitudes. Numerical analysis shows that the number of required subdomains increases linearly as the maximum tolerated approximation error decreases exponentially. 197 subdomains are required to keep the error below 1/8192 of the maximum amplitude. Quantum parallelism ensures that the computational complexity of estimating the amplitudes is independent from the number of subdomains.

WYOMING–EASTERN COLORADO

Silicic Acid Affects Growth, Productivity, and Quality of Alfalfa: Greenhouse and Field Study

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Mentor: Professor Anowar Islam

Alfalfa is the most important perennial forage crop. Application of silicic acid can impact growth, yield, and quality of alfalfa. The experiment was conducted at greenhouse and field environments. There were five treatments: 0, 1, 2, 3, and 4 ml silicic acid L^{-1}. Treatments were foliar sprayed biweekly. Growth data was measured monthly before harvest (four harvests). Results showed that silicic acid had significant effect on plant growth and dry matter (DM) yield of alfalfa. In greenhouse, control treatment produced lowest plant height, leaf length, leaf color, and DM. Leaf color increased with increasing silicic acid application with darkest green color at 4 ml silicic acid L^{-1} treatment. The 3 ml silicic acid L^{-1} treatment produced highest plant height, leaf length, and DM. Similar results were also observed in field study except for plant height and plant count in which there were no differences among treatments. In greenhouse, silicic acid application affected forage quality parameters of neutral detergent fiber, in vitro dry matter digestibility, and relative feed value. Silicic acid application had no effect on forage quality in field study. Overall, the results clearly indicate that foliar application of silicic acid can improve growth, yield, and quality of alfalfa.

The Development of an Electrothermal Ion Thruster

Matthew Murphy
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This year we have endeavored to modify the traditional system of an ion thruster and determine the effectiveness of this modification. In short, we have experimented with a new way of generating plasma and have significantly reduced the size of a typical thruster. Specifically, we have decided to replace the discharge cathodes found in most ion thrusters with an electrothermal accelerator as a new method of supplying the plasma. This allowed us to reduce the size of the thruster which is an important result to note since cargo space is a salient concern in designing rockets. Because we were able to construct a compact and functional ion thruster, it shows the potential to continue reducing the size of these key mechanical components of spacecraft allowing for the possibility of reducing rocket size for bigger craft. Another reason for using ion thrusters is that they are better for the mobility of spacecraft. They have a lower thrust, but a high specific impulse, ideal for mobility in space. When comparing the fuel efficiencies between chemical and ion propulsion, ion thrusters display efficiencies up to 90% while chemical thrusters only reach efficiencies of 35%. Ion thrusters also allow for spacecraft to travel at higher speeds, capable of accelerating them up to 90,000 m/s allowing journeys throughout space to be significantly less time-consuming. Ion Thrusters typically utilize the process of electron bombardment where a neutral gas is injected into the ionization chamber and bombarded with electrons generated by a discharge cathode. The free electrons in the propellant are knocked loose resulting in a plasma. These electrons are then pulled away by magnets creating a cation which is accelerated out the thruster via the electrostatic force generated by the electrodes. We took inspiration in our final ion thruster from a prototype that runs on a similar voltage input, but ionizes the oxygen gas in the air to produce thrust, rather than the plasma from the electrothermal accelerator. Our thruster incorporates the copper couplings as the electrodes similar to what their function was in the prototype. Our model takes the plasma supplied by the electrothermal accelerator and uses neodymium magnets to remove the free electrons creating cations which are accelerated by the electrostatic force coming from the electrodes out the thruster. We found that the Electrothermal Ion Thruster was able to fit in a cubic foot area and could be condensed to 3 key mechanical components: the electrodes, electrothermal accelerator, and the neodymium magnets. This thruster still proved to be effective as it showed capability to displace an object with a mass of 2.3 grams about 7.3 cm.

The Mitigation of Stress in *Danio rerio* Embryos Post *Valeriana officinalis* Exposure

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Teacher: Nikki Dobos
Mentor: Reese Titensor

Anxiety is a prevalent problem affecting millions of people around the world. Cortisol is secreted during stressful situations and long term impacts of cortisol within the body can lead to the development of chronic diseases, such as osteoporosis and type 2 diabetes. However, treatment for anxiety varies from prescribing medication, which can be expensive without the right insurance, to therapy based treatment. A proposed solution is utilizing the herbal remedy, *Valeriana officinalis* (valerian root), in combating the effects of anxiety in the body. *Valeriana officinalis* is a root known to have anxiety relieving effects. In this experiment, I will expose the *Danio rerio* (zebrafish) embryos to a set dosage(s) of *Valeriana officinalis* for 24 hours within their holding water, which will consist of their nutrients. I will then be measuring their cortisol levels by administering a heat shock stress-inducing treatment followed by an ELISA assay to quantify the amount of cortisol within the embryos. I hypothesize that the embryos exposed to the root will have lower cortisol secretion. I will compare the cortisol reading of the treatment groups to the control groups to analyze the efficacy of valerian root in mitigating stress within zebrafish embryos. I will be conducting a one tailed t-test to accurately compare the results of the experiment with a total of 30 data points. All waste will be properly disposed of in a biohazard bin. All hazardous chemicals and biological materials have been pre-approved by Kerry Hinton.