61ST NATIONAL JSHS

JUNIOR SCIENCE AND HUMANITIES SYMPOSIUM

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Abstract Catalog

The abstracts in this publication are from original scientific research conducted by participating students in the 61st National Junior Science and Humanities Symposium (JSHS). JSHS is a Department of Defense sponsored STEM program (U.S. Office of the Secretary of Defense and the U.S. Departments of the Army, Navy, and Air Force) that encourages high school students to conduct original research in the fields of science, technology, engineering, and mathematics (STEM) and publicly recognizes students for outstanding achievement.

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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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Section III
ABSTRACTS OF STUDENT PAPERS

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Impacts of Ocean Acidification and Elevated Temperatures on *Acusta Assimilis*

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Teacher: Dr. Susan Lagrone, Alabama School of Fine Arts Math/ Science

Ocean acidification and elevated temperatures are rising issues as they lead to substantial changes in the ocean's chemistry and have adverse effects on the ecosystem of oceanic organisms. This investigation studied the impacts of increased ocean acidification and elevated temperatures on *Acusta Assimilis*: shell mass, shell transparency, shell darkness, scarred structures, corrosion, and perforation. The hypothesis was that the most significant signs of degradation and decrease in mass of the *Acusta Assimilis* shells would occur at the lowest pH and the highest temperature. Conversely, the least significant signs of degradation and decrease in mass of the *Acusta Assimilis* shells would occur at the highest pH and the median temperature. The independent variables were the buffered solutions (pH 4,6,8) and the temperature environments (5.56°C, 22.22°C, 40.0°C). The dependent variables were the change in mass of the *Acusta Assimilis* shells, shell transparency, shell darkness, scarred structures, corrosion, and perforations. The major findings of this experiment were that the more acidic the buffered solutions, the greater the significance of shell degradation and change in shell mass. The greatest significance of shell degradation and difference in mass occurred at the highest temperature (40.0°C), and the least significance of shell degradation and difference in mass occurred at the median temperature (22.2°C). The Two-Way ANOVA test displayed a higher F-Ratio for each factor than the critical value. The three nulls tested by the Two-Way ANOVA were rejected, and the hypothesis for each was supported.

Does the Color of an Astronomical Body Affect the Observation of Decreasing Intensity with the Transit Photometry Method

Makaila Jennings
Key Destiny Homeschool, Huntsville, AL

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 the color of a Super-Earth 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 with three different colors (blue/green, red and yellow).

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 system for each color Super-Earth.

The results of my experiment support my hypothesis that the color of the Super-Earth does affect the ability to detect it with the double-dip transit photometry method. The yellow Super-Earth was the easiest to detect and it was detected the most with the red star.

Evolution of Oncogenic Signatures within Glioblastoma Along a Spatiotemporal Axis

Mayu Nakano
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Teacher: Tessa Magnuson

Glioblastoma is a malignant brain tumor distinguished by intra-tumoral heterogeneity and inevitable recurrence. Residual tumor-initiating cells in the infiltrated normal brain parenchyma, termed the tumor edge, generate molecularly distinct recurrent lesions, the eventual cause of patient lethality. Proteogenomics and non-negative matrix factorization (NMF) identified significant differentially expressed genes and pathways between the tumor core and edge. Identified genes were then analyzed at both the individual and whole genome levels. The tumor edge was found to be highly related to tumor cell infiltration and response to external stimuli. In turn, the tumor core was correlated with response to hypoxia and metabolic adaptation. Furthermore, transcription factor enrichment analysis revealed the oncogenic transcription factor FOXM1 as a central mediator within the tumor core. FOXM1 has been found to bind the protein-kinase MELK to regulate transcriptional activity of the enzymatic catalytic subunit EZH2, promoting radio-resistance. Individual expression analysis of FOXM1 revealed its upregulation to be associated with worse prognosis and treatment resistance. The expression signatures characteristic of tumor edge and core identified the anti-mitotic drug vinorelbine as a potential candidate for drug repurposing to target the FOXM1-dependent molecular shift between tumor edge and core. Collectively, this systematic comparison of tumor core/edge provides a coherent portrait of the prognostically-significant differences in molecular phenotypes associated with intra-tumoral heterogeneity within GBM tumors. This heterogeneity highlights the importance of robust analysis of the surgical unresectable tumor edge, which is the instigator of lethal GBM recurrence. This study also proposes the clinical application of proteogenomic analyses in precision oncology.

Designing a Hybrid 3D-Printed Piezoelectric Wheel for Energy Harvesting and Storage in Electric Vehicles

Naeim Mahjouri
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This research project targets the recent issue of limited energy storage and consumption efficiency in electric vehicles (EVs), which hinders their wider adoption. To tackle this challenge, the study aims to create a system that captures energy from the interaction between the wheels and the road as the vehicle is in motion, supplying it to the batteries and other electrical components. To achieve this, the piezoelectric effect is utilized by integrating piezoelectric materials, namely Lead Zirconate Titanate (PZT), into a 3D-printed wheel design. This 3D printing technique enables the customization of the flexible Piezo Wheel to maximize the harvested power output. An EV prototype with a Piezo Wheel (70mm diameter and 25mm width) using eight piezoelectric discs connected in series is constructed and found to generate a peak-to-peak voltage of 13.5 Volts at a speed of 3 meters/second. Additionally, experiments analyzing the effects of wheel speed, disc surface area, and force applied on the device output show positive correlations for each. The real-world feasibility of the system is demonstrated by powering the LED taillights of the prototype and measuring the time it takes to charge a 22uF capacitor up to 5 Volts. These results provide an opportunity to design flexible, complex, and efficient structures that can be incorporated into the wheels of EVs to enhance their energy efficiency.

ALASKA

The Relationship Between Gender and Areas of Academic Interest

Josephine Adasiak
Lathrop High School, Fairbanks, AK
Teacher: Patricia Garcia, Cibola High School

I designed this study to determine if there was a connection between gender and areas of academic interest for high school and college students. For a long time, there have been gender disparities in different academic areas, and I wanted to delve into that idea within my community. My hypothesis was that there would be a relationship between gender and area of academic interest, so to examine this potential correlation, I sent out a survey to high school students asking them their gender and area of most academic interest. I also got data about the gender breakdowns of different majors for a local university. I was able to analyze this data to look for any significant connections. By conducting a chi-square test, I determined that there was a correlation between gender and area of academic interest for high school and college students. Confidence intervals showed that college males tended to prefer things like math, engineering, and trade, while college females tended to prefer things like English, social studies, and the arts. They also suggested that high school males tended to prefer math, engineering, and computer science, and high school females tended to prefer science, medicine, and environmental studies, although both of those conclusions did not have a big enough sample size for statistically significant results. A clear correlation is shown between gender and areas of academic interest, and further studies might look into why this is the case.

The Difference in Correlation Between Attendance and Grade Point Average Throughout Secondary Education

Jonathan Brough
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This project was designed to determine if there is a difference in the relationship between attendance and grade point average (GPA) from middle school to high school. To test this, the percentage of school attended and a grade point average for 800 students within the Fairbanks North Star Borough School District ranging from grades 7 through 12 were provided by the school district. Confidence intervals for the slope of the regression line for middle school and high school were then calculated. Middle school had a slope of 4.3975, an R squared value of 0.3596, and a 95% confidence interval of (2.9538, 5.8413). High school had a slope of 4.6369, an R squared value of 0.3384, and a 95% confidence interval of (2.9088, 6.3650). Through this, no statistically significant difference in the relationship between attendance and GPA between middle school and high school was found. The confidence intervals for individual grade levels were also calculated and there was still no statistically significant difference for the relationship between GPA and attendance. This leads to the conclusion that there is no greater detriment to missing time in different grade levels throughout one's secondary education.

Center of Gravity and Distance Traveled by NERF Darts

Alexander Dahle
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My project is about how the center of gravity affects the distance a projectile can travel. The data I collected can explain how to balance a projectile to achieve the maximum distance possible. I hypothesized that the farther forward the 3D-printed weight was, the further it would go. I thought that because of my previous knowledge of playing darts with my friends. To test this, I mounted a brand new NERF Jolt to a custom-designed 3D-printed bracket to ensure each shot would launch at the same angle. I randomly selected in which order I would fire the darts with a cardboard spinner wheel I made. I then measured the distance the dart traveled and recorded the distance in Google Sheets. As the weight moved forward, the r^2 value increased, telling us that as the weight moved forward, it influenced the distance the dart went less. I was partially right and wrong. When the weight was further forward, it did better than the darts without the weight in the rear. However, darts with weight toward the front didn't do as well as the control group. These results surprised me and could be used to make rockets, missiles, or bullets more effective.

Quantitative Environmental DNA Metabarcoding for the Enumeration of Pacific Salmon (*Oncorhynchus* spp.)

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Understanding species abundance is critical to managing and conserving planetary biodiversity. Pacific salmon (*Oncorhynchus* spp.) are keystone species of cultural, economic, and ecological importance in Alaska and especially Southwest Alaska. Traditional methods of enumerating salmon such as weirs and visual surveys are often costly, time-intensive, and reliant on taxonomic expertise. Environmental DNA (eDNA), which identifies and quantifies species based on DNA they shed in their habitats, is a potential cost- and time- saving alternative. The relative ease of collecting eDNA samples also enables citizen scientist involvement, expanding research coverage. Currently, more research is required to define eDNA's potential and limits. This project investigates whether quantitative eDNA metabarcoding can accurately quantify the abundances of six fish species: the five Pacific salmon species plus rainbow trout. Water samples were collected from eight creeks in the Wood River watershed of Southwest Alaska. eDNA metabarcoding and subsequent bioinformatics processing produced a read count for each species. These were compared to visual survey counts, taken to be the true counts for the purposes of this study. Data analyses showed a positive, linear relationship between visual survey count and eDNA count for sockeye salmon. The regressions were significant for both the early ($p = 0.089$) and late ($p = 0.030$) sampling dates when $a = 0.10$. eDNA detections of non-sockeye species generally corresponded to visual survey observations of species presence or absence. Overall, the results of this study support eDNA's potential to be an alternative or supplement to standard methods for the enumeration of fish species.

A Study into the Equity of Dice

Joshua Wodrich
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The purpose of this experiment was to determine if six-sided, pipped dice are uniformly distributed. I hypothesized that sixes would have a higher probability of being rolled because the six side has more pips and therefore less weight to it. In order to obtain a significantly large sample, I randomly selected ten sets of nine dice. I rolled these a total of 180,000 times (18,000 per set), with which I compared to a single set of casino dice (generally considered fair) that I rolled 18,000 times. I then performed a chi squared goodness of fit test on both the traditional dice and the casino dice to determine if they were uniformly distributed, and a 1-sample p-interval on the proportion of sixes rolled to determine if the data was statistically significant. I discovered that dice rolls are not uniformly distributed (save for the casino dice rolls which were), and that sixes are statistically more likely to be rolled than any other value. This is consistent with my hypothesis because I initially theorized that sixes would be more probable. The results from this experiment are relevant because chance-based activities involving dice are unfair due to the uneven rolling probabilities.

ARIZONA

Hypothalamic EZH2: A Key Regulator of Leptin Sensitivity in Obesity

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Obesity is a severe health problem predicted to affect one in two U.S. adults by 2030. Leptin, an adipocyte-derived satiety-inducing peptide hormone, plays a critical role in mediating food intake and energy metabolism, with the levels of leptin production directly correlated to an individual's body fat mass. However, in obesity, leptin becomes ineffective in suppressing appetite and countering body weight gain, even though leptin and leptin receptor gene mutations are rare. Revealing the underlying epigenetic mechanisms in leptin resistance is essential for developing effective anti-obesity treatments. Since dietary and lifestyle factors can influence gene expression, obesity and leptin resistance were investigated through an epigenetics approach. We found that high-fat diet-induced obesity in mice is associated with significantly suppressed hypothalamic gene expression levels of enhancer of zeste homolog 2 (EZH2), a histone methyltransferase. After administration of EZH2-inhibitor into the brain of lean mice, a less pronounced decrease in food intake and body weight was observed. It was further observed that intermittent fasting improved leptin sensitivity in obese mice, accompanied by increased hypothalamic EZH2 gene expression to normal levels. After brain administration of EZH2-inhibitor, the leptin sensitizing-effect of intermittent fasting was significantly abolished. These results reveal, for the first time, the critical role of EZH2 in maintaining hypothalamic leptin sensitivity in the context of obesity and the benefits of intermittent fasting in recovering EZH2 expression in the brain. The study advances our knowledge of the epigenetic implications of leptin sensitivity and identifies a lifestyle intervention strategy to combat obesity.

Batch Adsorption Study of Methylene Blue Using Fresh Prickly-Pear Cactus as A Novel Model Material for Textile Wastewater Remediation

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Mentor: Dr. Derek Reichel, Roche Diagnostics

The textile industry is responsible for producing 20% of all water pollution. With Methylene Blue (MB) acting as the most commonly used basic dye in the textile industry, its usage results problematic as MB acts as a cancerous effluent, causing eutrophication in wastewater streams due to its dark color and non-biodegradability. Although previous studies have focused on the adsorption of MB onto chemically activated carbon, its usage results in release of silt into water which alters soil's composition, requiring high-cost treatment facilities for efficient usage. Using fresh, untreated biomass has been overlooked as a viable, and cost-efficient solution for wastewater remediation; fresh cactus is harvested across 2.6 M ha, it's recoverable in water unlike AC, and thus, a useful remediation tool. This study aimed to develop an understanding of the effectiveness of Opuntia ficus-indica as a potential adsorbent for MB by understanding how the parameters, such as contact time, adsorbent dosage and temperature may affect adsorption. Results indicated that decreasing temperature (25C to 4C), increasing time (1H to 24H) and increasing dosage (1g to 12.5g) all increased the average percent-removal of MB (up to 50.7%). The average concentration of MB removed from solution (mM/ per gram of cactus) decreased as the dosage increased. Therefore, we concluded that 1) the fresh prickly-pear cactus adsorbs the MB and 2) MB adsorption is dependent on dosage (g/mL), contact time (H) and temperature (C). MB can be remediated using the cactus as a viable (but less efficient) replacement for AC

GlucoseAssist: A Novel, Personalized System for Prediction of Blood Glucose Levels and Early Identification of Dysglycemic Events using Artificial Intelligence

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Blood glucose (BG) control is important for all individuals, especially diabetics, to evaluate and manage their metabolic health. Poor BG control results in dysglycemia. Frequent exposure to dysglycemia leads to cardiovascular disease, seizures, loss of consciousness, and potentially death. Today, many individuals struggle with BG control due to a multitude of interrelated behavioral, physiological, and biological factors such as food, insulin intake, and metabolism rate. There is a need for a solution that can accurately predict future BG levels, and dysglycemic events. However, current research uses limited input parameters, lacks potential meal-based predictions and is data-hungry and computationally expensive.

In this research, GlucoseAssist, a novel, personalized, AI-driven system, was developed to predict BG response in real-time and identify dysglycemic events based on diet, health, and medication data. Importantly, the devised system identifies the timing of the impending health events and provides preventative measures. The architecture uses a multimodal convolutional neural network and random forest classifier with time series data from a clinical dataset with 20,040 Continuous Glucose Monitor records. GlucoseAssist accurately predicts the BG response for the next 30 minutes with a Root Mean Squared Error of 1.230, nominal Mean Absolute Error of 0.920, and accuracy of 97.07% for identification of dysglycemic events.

GlucoseAssist demonstrates the feasibility of developing a data-driven solution that makes accurate, personalized predictions with a limited training dataset size. GlucoseAssist has the potential to positively impact over 911 million individuals' lives, who need a personalized, cost-efficient solution to help with BG control.

Examining Hindbrain Activation at Multiple Time Points Following a Small Intestinal Intralipid Infusion in Mice

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Obesity and diabetes are life-debilitating health conditions that may lead to life-long health complications. Energy homeostasis is tightly regulated, helping maintain food satiation and satiety that contributes to overall energy intake, and requires significant input from the gastrointestinal tract. Impaired energy homeostasis involves impaired brain signaling due to improper gut sensing and signaling of nutrients, leading to the increased food intake associated with obesity. In this study, we examine the gut-to-brain signaling pathway associated with maintenance of energy homeostasis and nutrient-induced satiation by examining the activation of the nucleus tractus solitarius (NTS) via the neuronal marker, cFos, at 30, 60 and 90 minutes after an intralipid or saline infusion in the small intestine of mice. Intralipid and saline were infused into the small intestine of mice through a surgically-implanted catheter and fixed brain slices were collected for immunofluorescent imaging and analysis. We found that intralipid increases cFos activation in the NTS at all three timepoints, with the greatest increase compared to saline at the 30-minute time point. The results lay the groundwork for future studies looking to target the small intestinal gut-brain signaling pathway and demonstrate the optimal time point for examining neuronal activation following a small intestinal nutrient stimulus.

A Mathematical Model to Forecast County-Level Crop Yield in Top Agricultural-Producing States Using Satellite Data

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Yield forecasting is critical for ensuring food security, especially given the rise of extreme weather events. However, the USDA NASS only provides state-level forecasts by conducting costly Objective Yield Surveys. This project proposed a simple yet effective method for forecasting the county-level yield of major crops in each state by utilizing remotely-sensed vegetation indices (VI) data. The vegetation indices were retrieved from the MODIS satellite on Google Earth Engine. Correlations were calculated between the final county-level crop yields and the monthly vegetation indices, with the highest correlation of 0.9177 occurring between the maximum VI of each growing season and county-level yield. Afterwards, a weighted regression was formulated to forecast the county-level crop yield by determining the coefficients between county-level vegetation indices and final yield along with the long term polynomial yield increase. The model is continuously retrained each year with new data and uses the updated coefficients to forecast the crop yield of the next year. The model was used to predict the corn yield of every county in Illinois and Iowa between the years of 2013 - 2021, achieving a median absolute percent error of 6.03% and 5.9%, respectively, throughout the 8 years. The model also achieved a highly accurate state level yield prediction between 2013-2021, with an overall mean absolute percent error (MAPE) of 3.69% for Illinois, compared to the USDA NASS forecasts MAPE of 4.31%. This model accurately predicts both county and state level yields at no cost, allowing for accessible yield forecasts.

ARKANSAS

VAST (Voice and Spiral Tool): A Novel Multimodal Machine Learning Method to Detect Parkinson's Disease and Assess Severity

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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 by a trained neurologist 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 2023 determined that currently, no machine learning model *(n=0/202)* has an accuracy of 90% or higher in detecting PD or assessing disease severity from voice and handwriting features. We propose VAST, the Voice and Spiral Tool, as a virtual diagnostic tool for the screening of patients with PD. Clinical specialists have a reported average accuracy of 79.6% to 83.9%. VAST is a state-of-the-art computational tool that validates the use of vocal features and demonstrates a 96% accuracy rate for PD diagnosis and assessment of disease severity (mild or severe) in individuals based on the *'Ah'* test (92% accuracy for diagnosis) and hand-drawn Archimedes spirals (100% accuracy for severity). Project VAST is successful in providing an accurate and effective method for PD diagnosis in a clinical or virtual setting through vocal and handwriting feature-based machine learning models. VAST may ultimately aid in accelerating PD diagnosis, resulting in improved clinical outcomes.

Early Detection of Acromegaly Using a Novel Convolutional Neural Network

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Acromegaly occurs when the pituitary gland produces too much somatropin, causing the liver to release excessive amounts of IGF-1, leading to the abnormal growth of the hands, feet, and face. Acromegaly is difficult to diagnose and can lead to serious, sometimes even life-threatening, health problems such as Type II diabetes and heart disease. The early detection of Acromegaly reduces potential health complications and the risk of death. Deep learning assisted early detection has now been proven feasible according to latest research and the prevalent success of Transfer Learning provides a potential path of non-computationally intensive detection. In this study, a dataset containing roughly 20 images were used to train a Convolutional Neural Network with Transfer learning that utilized ResNet-18 to mitigate the low dataset size. Firstly, Acromegaly and Non-Acromegaly images were placed into separate datasets and were further separated in a 70/30 training-validation split. This was run through the model, achieving a 65.62% validation accuracy over 25 epochs. This was paired with high training-validation loss values, 0.7/1.5 respectively, past epoch 25. To improve these losses, pairs of the same person were used to mitigate data imbalance within the datasets occurring from multiple same patient images. The datasets were comprised of Acromegaly/Non-Acromegaly (A/N) pairs and Non Acromegaly/Non-Acromegaly (N/N) pairs and each pair was fed through a custom data loader to then be fed through two Resnet-18 models, which were able to train on the differences between normal (N/N) and abnormal (A/N) growth. This led to a 9.9% validation increase as well.

Real-Time Sign Language Detector Using TensorFlow SSD Model and Python

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Communication is a means of passing on information to other people through verbal, written, or visual means. It constructs our social world and allows us to create bonds with others. People who are deaf or hard of hearing speak in sign language. Despite this, there is a linguistic barrier amongst deaf individuals because those with normal hearing lack knowledge of sign language. Technology-based solutions can be used to overcome this problem. This project builds a real-time sign language recognition system. The gestures for the dataset are collected using a Python program and the Webcam and labeled in the LabelImg package. A label map is created for each gesture and TensorFlow records are created. The TensorFlow object detection pipeline is set up and updated for training and trained on 20000 steps. The trained model is loaded from the latest checkpoint which was created during the training of the model. The real-time detection is then done using the Webcam, OpenCV, and Numpy. The confidence score is recorded and analyzed. An evaluation was done on the trained model to find the recall and mean average precision (mAP) to determine the performance of the model. The highest confidence score was the letter L with a 94% confidence score while the lowest confidence score was the letter O with only a 51% confidence score. The mAP was 0.714 and the recall was 0.747. These results show that the system was able to successfully train and can detect sign language gestures in real time.

Punicalagin Attenuates Chemotherapy-Induced Hepatotoxicity in Normal Cells

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Current research is focused on identifying drugs that can mitigate chemotherapy-induced side effects to normal tissues, while being cytotoxic to cancer cells. This study was designed to evaluate the potential protective effects of punicalagin against the hepatotoxicity induced by doxorubicin and cyclophosphamide in normal liver cells and its cytotoxic effects in cancer cells.

Clone 9 cells were pretreated with punicalagin (50 μM, 24 h) followed by doxorubicin (1 μM, 24 h) and cyclophosphamide (25 μM, 24 h). Cell morphology, intracellular reactive oxygen species (DCDFA Assay), protein levels of SOD2, catalase and GPx (western blotting) and intra cellular glutathione content was studied. Mitochondrial functions were studied by measuring intracellular ATP, MTT assay, TMRM uptake, JC-1 assay, and protein levels of Succinate dehydrogenase, VDAC, DRP1, and PGC-1α (Western Blotting). Cytotoxic effects of punicalagin with and without doxorubicin-cyclophosphamide in MCF7 cells was investigated by measuring cell viability and cell morphology.

Punicalagin exhibited robust protection against chemotherapy drug-induced ROS generation by preserving the antioxidant defense system, which was evident in cell morphology. Punicalagin pretreatment also protected mitochondrial functions by significantly preserving ATP content, maintaining mitochondrial membrane potential and levels of critical proteins. Combined treatment of punicalagin and doxorubicin-cyclophosphamide killed 90% of the breast cancer cells, while punicalagin treatment alone had 49% cytotoxicity.

In conclusion, punicalagin demonstrated robust protective effect against chemotherapy-induced damage to normal liver cells, while augmenting the cytotoxic effects in combination with chemotherapeutic drugs in cancer cells, suggesting that punicalagin may be considered as a potential adjuvant drug during and after chemotherapy.

Improving Early Diagnosis and Treatment Monitoring of Tuberculosis with Novel Machine Learning Cough Analysis

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Tuberculosis (TB), a bacterial disease mainly affecting the lungs, is the leading infectious cause of mortality worldwide before COVID-19. To prevent TB from spreading within the body, which causes life-threatening complications, timely and effective anti-TB treatment is crucial. Cough, an objective biomarker for TB, is a triage tool that monitors treatment response and regresses with successful therapy. Current gold standards for TB diagnosis are slow or inaccessible, especially in rural areas where TB is most prevalent. In addition, current machine learning (ML) diagnosis research, like utilizing chest radiographs, is ineffective and does not monitor treatment progression. To enable effective diagnosis, I developed an ensemble model that analyzes, using a novel ML architecture, coughs' acoustic epidemiology from smartphones' microphones to diagnose TB. The architecture includes a 2D-CNN and Boost that was trained on 724,964 cough audio samples and demographics from 7 countries. After feature extraction (Mel-spectrograms) and data augmentation (IR-convolution), the model achieved a 94% sensitivity and 87% specificity, surpassing WHO's requirements for screening tests. The bi-directional LSTM utilizes periodic cough history and the 2D-CNN confidence score to predictively monitor response to TB therapy with the treatment-irregularity algorithm (TIA). The LSTM and TIA effectively (AUC<0.28) monitor the body's reaction to anti-TB drugs through changes in cough patterns, allowing the ML model to predict a high risk of treatment or dosage irregularity. This early detection of drug irregularity can avert TB relapse, drug-induced liver injury, and drug-resistant strains. This research demonstrates the architecture's effectiveness in improving TB diagnosis and predictive monitoring.

CALIFORNIA NORTHERN

A Novel Home-Built Metrology to Analyze Oral Fluid Droplets and Quantify the Efficacy of Masks

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Every year, 4 million people die from upper respiratory infections. Mask-wearing is crucial in preventing the spread of pathogen-containing droplets, which is the primary cause of these infections. However, most experiments for evaluating mask efficacy are either expensive and complex or inaccurate. In this work, a novel, low-cost, and quantitative apparatus to visualize, track, and analyze orally generated fluid droplets is developed. The project has four stages: setup optimization, data collection, data analysis, and application development. The setup was initially constructed in a dark closet as a proof of concept using common household materials and was subsequently implemented into a portable apparatus. A fluorescence-based technique utilizing tonic water and UV darklight tube lights is used to visualize droplet and aerosol propagation with automated analysis conducted using open-source software. The dependencies of oral fluid droplet generation and propagation on various factors are studied in detail and established using this metrology. Additionally, the droplet size was mathematically correlated to height and airborne time. The setup is sensitive enough to capture droplets as small as a few microns. The efficacy of different types of masks is evaluated and associated with fabric microstructures; it is determined that masks with smaller sized pores and thicker material are most effective. This technique can easily be constructed at home using materials that total to a cost of less than $60, thereby enabling a low-cost and accurate apparatus.

Effect of RootPipes on Landfill Gas Emissions

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With climate change's increasing impacts, we must reduce anthropogenic greenhouse gas emissions, specifically methane, to lower the intensity of cascading disasters. In 2019, landfills contributed to 15% of the total methane emissions in the US. In landfills, the absence of oxygen causes the anaerobic decomposition of waste, leading to a significant formation of methane. Inefficient extraction systems in current landfills cause 46% of this methane to release into the atmosphere. To create a more sustainable landfill system, RootPipes were developed: they take inspiration from the shape of mangrove roots and reach remote locations of the landfill to optimize gas collection. A 3D-printed prototype of RootPipes was designed and tested by simulating two landfill environments—RootPipe and current landfills. Compostable waste was added into both landfills, which were sealed to promote anaerobic decomposition; the gasses formed were able to exit the compost area through the pipes into a designated empty area. After 5 months of data collection, the pressure of the gasses accumulated was greater for RootPipes than current landfills, indicating that RootPipes could transfer more gasses to the empty area. The temperature of the current landfill was higher, so more methane was trapped in the compost. Overall, RootPipes collected 78% more gasses than the current landfill system. This translates to 91% collection and 9% emissions when scaled to large-scale landfills. Due to thorough extraction, more gasses can be converted to renewable energy, gathering more revenue and removing reliability from fossil fuels.

Sprayable, Biodegradable, Thermoresponsive, Antimicrobial Hydrogel Wound Dressing

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Wound dressings are critically important to wound treatment and healing. Conventional wound dressings are prefabricated, non-degradable, non-conformal, and contain silver particles. Not only are these difficult to use for irregularly shaped wounds, wounds with varying depths, and wounds with large surface areas, but they require frequent changes, which disrupts healing, causes pain, and increases risk of infections. Furthermore, at high concentrations, silver ions are cytotoxic to fibroblasts and stem cells, which may hinder tissue growth and cause excessive scarring. This project is a sprayable, biodegradable, intrinsically adhesive hydrogel dressing that does not need to be changed while time-releasing antimicrobial agents. The formulation is a sprayable, reverse thermal hydrogel that is directly sprayed on the wound and releases borate, a safe anti-infective agent with broad-spectrum antimicrobial activity and wound-healing properties. It contains Poloxamer-407, a biodegradable reverse-thermal block copolymer of poly(ethylene oxide)-poly(propylene oxide)-poly(ethylene oxide), and a biodegradable poly(vinyl alcohol)–borate complex for extended-release of borate. Chitosan and polyols like mannitol and trehalose are added for homogenous incorporation of the PVA-borate complex into the Poloxamer-407 solution. The formulation has a pH 5.0-6.0, close to the optimal pH for wound healing. With optimized pH, composition, and molecular weights of chitosan and poly(vinyl alcohol), the dressing formulation has a gelling temperature of 24-26°C, enabling its rapid transition from a solution to a gel form at body temperature when sprayed on the wound. For extended applications, other topical antimicrobial agents, pain relievers, and tissue engineering and hemostatic biomaterials can be delivered by this formulation.

MADLIBS: A Novel Multilingual Data Augmentation Approach for Low-Resource Neural Machine Translation

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Neural Machine Translation (NMT) has been established as the dominant approach for developing state-of-the-art translation systems, but its effectiveness depends substantially on the availability of large parallel corpora, resulting in a significant performance gap in low-resource settings. With the declining diversity of the world's languages, accessibility to low-resource NMT systems is valuable for promoting inclusivity. To address this, I propose a novel Data Augmentation (DA) method suitable for underrepresented languages, MADLIBS, **M**ultilingual **A**ugmentation of **D**ata with Alignment-**B**ased **S**ubstitution, which generates diversified sentence pairs without auxiliary data.

The approach consists of three components optimized for the low-resource setting: an attention-based encoder-decoder aligner, a semi-supervised POS-tagger, and a template generator. From the templates, constructed from existing sentence pairs, aligned source-target word pairs are replaced with plausible substitutions.

Experimental results on a range of linguistically diverse languages in the extremely low-resource setting show improvements in translation quality by up to +3.4 BLEU points over the baseline, and +0.5 BLEU over the current established DA method, Back-translation, even without the use of monolingual data. I surpass the results of the top state-of-the-art OPUS-MT model on the leaderboard for one task.

The method demonstrates great contributions towards advancing in one the most prevalent and difficult challenges of deep learning and in one of the most complex modalities and tasks. It contributes an effective and fundamentally unique approach. It is a step forward in the current frontier of DA research. The work further presents potential for emerging methods towards preserving endangered languages with NLP.

Enabling Ankle-Brachial Index Prediction from Doppler's Using Deep Learning for Peripheral Arterial Disease Diagnosis

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Peripheral Arterial Disease (PAD) is caused by the blockage or narrowing of arteries supplying the lower extremities regions which affects approximately 10% of the U.S population and is one of the leading causes of limb amputations world-wide (approx. 50%). The current clinical procedure used for the identification of PAD involves the Ankle-Brachial Index (ABI) examination. The ABI is a metric calculated by dividing the ankle-tibial blood pressure (BP) measurement from the brachium and is a definitive procedure for PAD diagnosis. The value can be categorized for specific clinical outcomes and workflows. However, the ABI is currently challenged due to its vast limitations such as the in-accessibility of measurement across patients afflicted by diabetes, renal disease, and more, due to calcification of arteries and falsely-elevated measures. Additionally, ABIs are time consuming and potentially subjective. If ABIs are unable to be accurately measured at the point-of-care setting, patients are referred to formal vascular laboratories where treatment is significantly delayed. This project proposes a custom signal processing based deep learning system which can accurately classify ABIranges from tibial doppler flow of the ubiquitous hand-held continuous wave doppler, enabling accurate point-of-care ABImeasurements, which are fast, simple, and accessible to all patients without having the problem of falsely-elevated measures caused by calcified arteries. The proposed algorithm has undergone significant statistical validation and has received a classification accuracy of 98.85%

CALIFORNIA SOUTHERN

A Deep Learning-Based, Bioinformatic Analysis of Foliar Fungal Endophytes in Litter Decomposition

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Litter decomposition is a key ecological process that plays a vital role in the global carbon cycle. While the effect of soil microbes in decomposition has been well studied, the role of fungal microbes within the leaf, or foliar fungal endophytes, is largely unclear. In the present study, the relationship between endophyte abundance and litter mass loss was examined in the Torrey pine (Pinus torreyana). Total DNA and RNA was extracted, followed by next-generation sequencing and bioinformatic analysis to identify core endophyte species across geographic regions. Endophyte abundance was discovered to be positively correlated with mass loss, and endophytes OTU4 and OTU211 were most prevalent throughout all samples. In addition, based on open-source data, OTU4 has not been previously discovered in Southern California, where the samples were collected. This understanding of plant decomposition and its relevance to the global carbon cycle is essential, particularly in the current climate change era.

Internet-of-Things Connected Foley Catheter Urine Collection System to Automatically and Continuously Measure Urine Output

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Mentor: Hsi-Jen James Yeh, Ph.D., Associate Professor and Chair at Azusa Pacific University

Urine output is an important indicator of the level of renal impairment in patients. Accurately measuring urine output is critical in the treatment of hospitalized patients with renal injury, heart failure, and other life-threatening conditions. Currently, the most common way to collect urine uses a Foley catheter connected to a urine collection bag that has volume gradation markings. This measurement method has a low level of accuracy and is labor-intensive, requiring a nurse to manually measure the urine collected periodically. This project developed an Internet-of-Things enabled system that captures urine output automatically in real time, by continuously monitoring the urine volume collected via the Foley catheter. The device is built utilizing a strain gauge load cell, an integrated circuit that contains an amplifier and analog-to-digital converter, and a WiFi-enabled microcontroller. The data is sent via wireless networking to a data collection and analysis server which provides accurate analyses of urine output. A mobile application utilizing the Blynk.io system is used to display the data. This device and mobile application were built at a minimal cost of $35 USD. The device has been tested multiple times and reported urine output accurately, with as little as 1% difference between actual vs measured volumes. In the future, further development of this device can provide hospitals and physicians worldwide with easy access to affordable, accurate, and real-time urine measurement, which would translate into better, life-saving medical care.

Novel Bilayer Elasto-Hydrogel Adhesive Film for Facilitating Wet-Occlusive Therapy for Atopic Dermatitis

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Mentor: Dr. Jonathan D. Pillai, National Biotech Cluster, Translational Health Science and Technology Institute

Atopic dermatitis (AD) is a common chronic multifactorial skin disease that causes skin inflammation owing to defects in the skin barrier, immune dysregulation, or infectious agents. The most common treatment of AD utilizes wet-occlusion therapies to create a protective skin barrier by providing moisture to the epidermis. However, these treatments are suboptimal in managing disease symptoms owing to their limited ability to retain or restore skin hydration and inefficient drug delivery. Currently, there are no effective approaches for treating AD that are specifically designed to improve drug delivery efficacy and skin hydration. This study aims to introduce a new approach of localized drug delivery and facilitate more efficient dermal hydration using hydrogels and elastomers. Herein, we report a simple yet effective bilayer elasto-hydrogel adhesive film (BEHAF) dressing made from an interpenetrating alginate and polyacrylamide (alginate/AAm) hydrogel layer backed by a thin film of polydimethylsiloxane elastomer. In an *in vitro* hydration study, it was found that the BEHAF dressing enabled efficient retention and delivery of hydration to porcine skin and model epidermis for more than 48 h and showed potential for drug delivery of both hydrophobic and hydrophilic drugs. Furthermore, mechanical testing results indicate that the BEHAF mimics the elastic behavior of human skin and shows good adhesion sensitivity, thereby suggesting biomechanical compatibility and suitability for long-term usage. Overall, the BEHAF dressing may provide a viable vehicle for dermal hydration and drug delivery, thereby improving the efficacy of wet-occlusive therapy for treating AD.

Hepatitis B Patient-Derived Virus Exhibits Replication Step-Dependent Resistance to Interferon in a Chronic in-vitro Infection Model

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Chronic Hepatitis B virus (HBV) infection affects 300 million people worldwide, with no existing cure. The first-line treatment is interferon (IFN), an antiviral cytokine. However, clinical IFN therapy only reduces HBV DNA levels in 25% of patients, suggesting that some exhibit resistance to IFN. Genotype, viral load, and other factors are hypothesized to influence this resistance. Conversely, research studies show that IFN treatment consistently reduces both HBV DNA and viral protein levels. To investigate the contradiction between clinical and laboratory research findings, infectious virions of varying genotypes and propagation methods were cultured using a highly physiologically relevant model: humanized liver chimeric mice-derived human hepatocytes (HLCM-HHs).

To examine IFN's direct effects, HBV-infected HLCM-HHs were treated with IFN-alpha and IFN-beta for 10 days, and pre-genomic HBV RNA, extracellular HBV surface antigens, and HBV DNA levels were measured. The results revealed resistance to exogenous IFN among patient-derived inocula, despite induction of IFN-response genes in all inocula. Then, to validate these findings, HLCM-HH's were coinfected with Hepatitis Delta Virus (HDV), a satellite virus of HBV that induces the IFN response. HDV coinfection reinforced previous results: HBV DNA levels were not affected when treated with three genotypes of patient-derived inocula, despite IFN-response gene induction in all six. The patient-resistant samples differed in genotype between these experiments, implying that in-vitro HBV resistance to IFN is genotype-independent. Ultimately, this study establishes a correlation between HBV DNA and HBsAg reduction among patient inocula regardless of genotype, elucidating novel mechanisms of IFN resistance for improvement of clinical IFN therapy.

A Microfluidic Liver Chip for Evaluating Idiosyncratic Drug-Induced Liver Injury

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Mentor: Dr. Hao Tang

Idiosyncratic drug-induced liver injury (iDILI) is a rare but potentially severe form of liver damage that occurs as a result of certain medications. It is characterized by liver inflammation and damage that is not directly caused by the toxic effects of the drug, but rather by an immune response to the drug. Previous iDILI research such as low-dose LPS animal models are not able to promptly detect hepatic inflammation and the parameters of these models often change with the drug being studied. In this study, microfluidic technology was employed to create a laminated liver chip containing HepG2, U937 macrophages, LX-2, and EA.hy926 cells, as well as an inflammation model, and evaluated the known iDILI drug troglitazone. The results of this research demonstrate that the combination of troglitazone and LPS significantly increases liver cell damage and the production of inflammatory factors TNF-α and IL-6. This evaluation method, which mimics the microenvironment of the human liver, can partially compensate for the limitations of animal models and in vitro models. The chip also allows for the examination of different inflammatory conditions and the impact of drugs on the liver, providing a more comprehensive understanding of iDILI. Overall, this research presents a new and promising method for the study of iDILI, which can aid in the development of safer drugs and treatments for liver injury.

CONNECTICUT

Creation and Simulation of Function of Claramine-Atorvastatin Coated Hyaluronic Acid Nanoparticles for Targeted Dissolution of Atherosclerotic Plaque

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Teacher: Andrew Bramante, Greenwich High School

Atherosclerosis, the buildup of lipids as a plaque within the inner lining of the blood vessel wall, leading to reduced vessel flexibility, is the result of a cut in the layer of activated endothelial cells, allowing for the accumulation of lipids and foam cells within the artery. It is common and eventually causes myocardial infarction and strokes, making it crucial to treat. As typically prescribed statins do not always work, invasive surgery is left as the only other option. Thus a novel, targeted therapeutic of claramine-atorvastatin coated hyaluronic acid (HA) nanoparticles was created in this research. First, HA was conjugated to lithocholic acid to create an amphiphilic polymer that self-assembled in aqueous conditions in nanoparticles when sonicated. These CD44 (inflammation) targeting nanoparticles were then coated with claramine, a PTP1B inhibitor, atorvastatin, as well as FITC for visualization. To test the efficacy of these nanoparticles, THP-1 monocytes were differentiated into foam cells with lipopolysaccharides, PMA, cholesterol, and LDL. Once treated with coated nanoparticles, an 88x-decrease in cell proliferation was observed using a WST-8 assay, suggesting a decline in the creation of diseased cells and inflammation. Intracellular-fluorescence studies highlighted the nanoparticle's selectivity only for diseased foam cells, while they did not enter healthy monocytes. In a 3D-carotid artery bifurcation model containing agar/diseased cells plaque, serum/media cholesterol levels decreased post-nanoparticle therapy, highlighted by ATR-FTIR studies. Finally, it was determined that nanoparticles are stable in aqueous solutions, pointing to their integrity until they reach the CD44 receptor for phagocytosis and drug delivery.

Design of a Novel, Dual-Functioning, Tissue Plasminogen Activator and Factor XI Inhibiting Anticoagulant Therapeutic for Rapid Ischemic Stroke Treatment

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Stroke is the second leading cause of death worldwide, with 15 million people suffering from its debilitating effects each year. 87% of strokes are ischemic, where an artery narrows or becomes wholly blocked due to a thrombus. Tissue Plasminogen Activator (tPA) is a protein that activates the conversion of plasminogen to plasmin, an enzyme responsible for the breakdown of clots. While tPA is the leading emergency treatment for ischemic stroke, it possesses several shortcomings, including a non-localized nature and increased risk of hemorrhage. Similarly, no existing therapeutic candidates have dissolved the thrombus and simultaneously deterred the coagulation cascade, the process by which a thrombus is actively built. Herein, a rapid, clot-specific, and dual-functioning microbubble system utilizing tPA and a Factor XI inhibiting polyclonal antibody was engineered to create a more effective emergency therapeutic. To begin, fabrication of the magnetic interior nanoparticles was completed by synthesizing Dicumarol-Carboxylic-acid coated Fe_3O_4 nanoparticles in the first iteration of the interior structure. Next, SiO2-tPA was fabricated and added to complete the subsequent encapsulation layer of the nanoparticles. After sonication and synthesis of a "microbubble" structure, peptides CGSSSGRGDSPA and GRGD were conjugated to the exterior to promote selectivity for platelets and fibrin and ensure clot-specific adhesion and release. A vertical gel channel system, composed of fibrinogen, thrombin, and agarose, was developed to validate the clot dissolution as a function of the new therapeutic, which was 2x that of tPA alone. As a final verification component, *in-vitro* clots were created using ~100μl of whole-blood in a 96-wellplate.

Assessing the Impact of Synthetic Sweeteners on Hunger Perception in *Drosophila Melanogaster*

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The consumption of natural sugars leads to a dopamine surge in the nucleus accumbens, a vital area of the mesolimbic dopamine system. Artificial sweeteners, a low-calorie alternative to natural sugars, are typically marketed toward individuals with diabetes and other health conditions that require low-calorie diets. Since artificial sweeteners are zero-calorie, they are not metabolized into units of usable energy, meaning that they cannot fully activate reward pathways and cause a dopamine increase. This known characteristic could potentially lead to an increase in quantity of consumption in an attempt to fully activate the dopamine system's neurological pathways.

This research seeks to determine whether consuming three different synthetic sweeteners leads to an increase in quantity of consumption when compared to sucrose, a natural sugar.

Four groups of eight wild-type *Drosophila Melanogaster* were fed either a control 3M sucrose solution, a 5% sucralose solution, a 5% acesulfame-potassium solution, or a 5% aspartame solution. Flies were monitored over periods of 1 and 3 days. Food consumption was measured using the Capillary Feeder Assay. Liquid food was presented to Drosophila in glass capillaries placed in a vial. As the liquid is consumed, the capillary meniscus declines.

Based on the t-test statistical analysis, *Drosophila Melanogaster* consumes up to twice as much synthetic sweetener as it does pure sucrose solution (≈61.84% increase in sucralose consumption, ≈68.09% increase in acesulfame-potassium consumption, ≈93.75% increase in aspartame consumption). This research establishes the impact of artificial sweeteners on quantity of consumption when compared to a natural sugar.

Implementing Nontoxic Modified Biochar Enhanced Filtration for the Efficient Removal of Emerging Contaminants in an Aqueous Solution

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Mentor: Alyssa Anderson

Many water sources contain emerging contaminants that currently lack sufficient regulation but lead to debilitating health and environmental effects, yet current standard water treatment processes cannot remove most such contaminants from water. This project researches the usage of doped biochar enhanced by the addition of metal oxide nanoparticles for removing specific emerging contaminants, namely pharmaceuticals, pesticides, microplastics, and oil, from water. Biomass content derived from either coconut shell or rice husk, both of which are abundant natural scrap materials, was individually pyrolyzed into biochar. Further, each biochar sample was separately tested with the enhancement of synthesized Fe3O4 and MnO2 nanoparticles. With biochar's advantageous adsorption properties further enhanced by the increased surface area available for sequestration of contaminants through the addition of metal oxide nanoparticles, it was expected that an efficient contaminant removal method would be devised. Pharmaceutical and pesticide removals were measured using liquid chromatography mass spectrometry (LC-MS), microplastic removal was measured using digital WiFi light microscopy, and oil removal was measured using light spectrometry. Coconut shell biochar enhanced by the addition of Fe3O4 nanoparticles was the most effective design tested, removing 65.69% of acetaminophen and 50.09% of ibuprofen (pharmaceuticals), 61.05% of glyphosate and 66.31% of DEET (pesticides), 56.26 % of PETE microplastics, and approximately 71.83% of gasoline oil. This demonstrates considerably efficient removal through this inexpensive, environmentally friendly, easily implementable, and sustainable method. A prototype of a standard filter with compartments for sand and biochar filtration developed using 3D modeling software and will be further refined for real-world implementation.

Concurrent Removal of Rising, Soluble Ocean Carbon Dioxide and Oil-in-Water Contaminants via Multi-Functional Remediation Framework

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The oceans absorb nearly a third of airborne CO2 emissions, while concurrently, 1.3 million gallons of crude oil are spilled into oceans every year. Both issues continue to detrimentally affect marine biodiversity, and the future of human health. This research provides a highly efficient/practical method for the concurrent removal of CO2 and soluble oil-in-water contaminants through the creation of a Multi-Functional Remediation Framework (MF-RF) utilizing hypercross-linked polymers (HCPs), synthesized from Styrofoam. First, Styrofoam HCPs were synthesized through a one-pot Friedel–Crafts reaction according to Dong et al. HCPs alone remediated 88% of the 1.7g/L-soluble-benzene in seawater (via measure of benzene's fluorescence). Regarding CO2 95% of the contaminant was removed, or $3.12E^{-5}$M[CO2]=[H^+] (via pH measure). For the MF-RF, HCP-sponges were constructed on 8x1.3x0.7cm of melamine, with PTFE adhesion, and 450mg HCP for pollutant removal/capture. Air-tight modeling of the sponge benzene/CO2 remediation were subsequently constructed. HCP-sponges remediated 92% of the 1.7g/L-benzene contaminant, and 95% of CO2 (3.12E-5M[CO_2]=[H^+]). Realistic concurrent oceanic experiments with a 0.1pH difference and maximum solubility of benzene highlight 92% remediation of oil, with only 12.6min needed to reach suitable oceanic pH. High-load concurrent removal experiments with 100x more CO2 demonstrate 71% remediation of oil and 85% remediation of CO2. Via recycle/reuse studies, the MF-RF may be reapplied in contaminated water until its capacity is reached (5.99g oil/HCP-sponge and 3700ppmCO2/HCP-sponge). Stability studies demonstrate prolonged MF-RF integrity, as a dual-functioning, marine-safe, easy-to-use oil and CO2-remediation tool, which is simply lowered into contaminated water, left until saturated, and then lifted out for contaminant.

DODEA EUROPE

Spotify + the Machine (Learning): Tracking Song Audio Features

Katrina Chao
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Teacher: Daniel Coapstick

As the global music streaming industry grows at an increasing rate, with Spotify dominating the market, personalized playlists and recommended artists and songs curated for each user are often the reasons behind these popular streaming platforms. An advantage of Spotify is its API, which allows the researcher to look deeper into the differences between "Happy" and "Sad" music. With Spotify Audio Features, an in-depth analysis of danceability, energy, valence, and more can be used for machine learning. This researcher looked into supervised machine learning algorithms like Support Vector Machines to classify sad and happy music. With the potential in other machine learning algorithms, there is hope for more personalized playlists based on a user's mood.

How Sharing Seemingly Irrelevant Information May Prove to be a Vulnerability

Anna Galeano
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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 study is to evaluate the vulnerability of current active duty service members on the social media platforms LinkedIn and Facebook. Both prompt 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 procedure. Organizational Risk Analyzer (ORA) is then used to identify the most influential accounts and establish social networks to be presented in a manner that is comprehensible.

Which Freshmen High School Students Have a Higher Social Intelligence: Gamers or Non-gamers? A Quantitative Study

Javier Harrington
Ramstein High School, DoDEA

The purpose of this quantitative study was to test the Social Intelligence of both: gamers and non-gamers freshmen high school students. The study had a sample that consisted of 86 participants. All participants completed an online Social Intelligence Test. In conclusion, the gamers got a higher Social Intelligence score in comparison to the non-gamers group.

Training Neural Networks Using Reinforcement Learning: The Application of AI in the Twenty-First Century

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Teacher: Dr. Harrington, Ramstein High School

With the development of new AI technologies, such as OpenAI's chatGPT, our lives have become influenced by the factors of AI benefits. In this qualitative study, the researcher explored the field of reinforcement learning by running two simulations with potential solutions to real-world specific problems. To perform these, the researcher used the program Unity with the plugin UnityML, and also python as a coding language. The results of the simulations provided valuable feedback on the training of neural networks using reinforcement learning. We can see direct correlation between the generated graphs and the learning patterns, such as the cumulative and episode length. In summary, both simulations proved themselves to be potential solutions to these specific issues.

Appropriation of African American Culture in Disney Animated Films

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Over the past 30 years racial representation amongst Disney animated films have changed significantly, becoming more inclusive and diverse. This study aims to understand the cultural accuracies and inaccuracies in Disney's proclaimed diversification of its animated films. Using the Research of Colin Roedl, Jennifer Barker, Richard Breaux, Megan Condis, Zelda and Sarita Gregory, this project aims to "dig a little deeper" in African American representation in Disney Animated films. Specifically looking at The Princess and the Frog, Soul, and Spies in Disguise. This study aims to answer, "Are African American Leads the Film's Protagonist as promoted, or do they lose focus after turning into an animal? This will be done close examination of the Disney Animated films featuring an African American lead stated above.

DODEA PACIFIC

Topographic Geographic Information System Mapping as Approach to Reducing Region of Interest for Radiation Detection by Unmanned Aerial Vehicles

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In the aftermath of large-scale radiation release, spatial distributions and quantities of released radionuclides must be established as a crucial aspect of response management in order to inform on-site incident management strategies and evacuation plans. Recently, radiation monitoring systems based on unmanned aerial vehicles (UAV) have been widely studied and employed. Estimation of the distribution of radiation distribution on a map is important, as it reduces the region of interest (ROI) for field characterization and source localization. This informs people of possible radiation hotspots and also results in more efficient airborne radiation mapping. This project analyzes radiation distribution patterns to find trends that help predict hotspots--reducing the ROI--and tests the accuracy of the identified regions. It was hypothesized that use of an ROI would significantly decrease the land area surveyed through UAV, with accuracy. Trends were compiled from previous research and hotspots were identified within a 100 kilometer radius of the Fukushima Daiichi Nuclear Power Plant. Two groups were identified: the control group, which was the map not reduced, and the experiment group, the map with specified ROIs. Radiation doses were taken from both groups and entered into an ANOVA calculator. Doses within the ROI group were significantly higher than the control group (P=.006). Furthermore, the land area of the ROI map (3743 km^2) was 66% lower than the control map (14689 km^2). This presents a method of using topographic maps in order to reduce the ROI for radiation monitoring by unmanned aerial vehicles.

Does Recovery Between Exposures Decrease the Toxicity of Zinc to Fathead Minnows?

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Heavy metal pollution in water sources has detrimental effects on aquatic life. Everything from the amount of dissolved organic carbon (DOC) in the water to the pH of the water can affect how bioavailable and therefore toxic the heavy metal is in the water (van Genderen et al., 2009). The Biotic Ligand Model was created to predict toxicity of metals (di Toro et al., 2001). The Biotic Ligand Model considers many water quality criteria that affect bioavailability, but it does not include one important aspect of poisons in water: exposure time (Colvin et al., 2021).

This experiment included single pulse and double pulse exposure and ran for a total of 21 days to model real life events of rainfall and to give adequate time for long-term effects to display (Colvin et al., 2021). Single pulse treatment was 24 hours of zinc and double pulse was a total of 24 hours of zinc with a 24-hour gap at the 12-hour mark. While the data did not end up being statistically significant, the apparent trends validate the hypothesis that giving a 24-hour break in zinc exposure gives time for recovery in the fathead minnows. With the apparent trends, episodic exposure can be seen as a contributing factor to organism mortality since it allows the organisms to recover from the same amounts of zinc exposure. These results should be considered in future studies and environmental regulations as they validate that episodic exposure does have an effect on mortality.

The Effects of Mechanical Stress on Male and Female *D. melanogaster* General Activity and Survivorship

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An estimated 280 million people have Major Depressive Disorder (MDD), a disorder that affects females and males differently. Within the field of MDD research using *Drosophila melanogaster*, flies' neurological and behavioral responses are measured as flies are induced into a depressive-like state (DLS) often through exposure to uncontrollable stress. However, there is a lack of investigation into sex-based differential responses. This experiment subjected male and female flies to mechanical stress caused by vibration for 9 hours a day for three consecutive days, collecting data regarding flies' general activity and survivorship. As low activity indicates a DLS, male flies were predicted to have much lower general activity levels than females when compared with corresponding control groups. After three days of treatment, locomotor tests were inconclusive. All flies had much higher general activity rates following vibration or control treatments, indicating a need for future procedural revisions. However, significantly more male experimental flies died ($p=0.003$) demonstrating that male flies were more affected by the mechanical stress. Future research may seek to understand physiological causes of this trend. As more is understood regarding differential sex-based mechanisms in *Drosophila*, human diagnosis and treatment of MDD may also improve.

Selectively Breeding *Zophobas Morios* for Polystyrene Degradation

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Over the past decade, scientists have discovered species of plastic-eating worms, a key to unlocking how to degrade recalcitrant plastic. Plastic-eating worms have the ability to degrade plastic back to their monomers, a revolution to the recycling processes since plastic can only be recycled 2-3 times before their polymer bonds grow too weak. Therefore, selectively breeding worms to increase their plastic consumption can provide a viable yet practical solution to abating landfill plastic waste. In this study, to test the hypothesis that *Zophobos Morio* worms can increase their plastic consumption through selective breeding, three control groups from the control F3 generation, and three experimental groups from the treatment (1:1 ratio of plastic + bran diet whilst only selecting 10% heaviest to breed) F3 generation were compared for their plastic consumption over a 32-day period. Control variables were kept constant with a humidifier and heater that was turned on 24/7 for the course of 15 months with no power outages (26 ± 1 °C and 50 ± 10% relative humidity.) F3 experimental groups showed on average a 1.8 milligrams of increase in plastic consumption per worm, and then statistical analyses were performed. The results were proved extremely statistically significant with the largest p-value out of the three being *2.6668912E-27*. Because all three p-values were approximately zero and consistently relative to each other, the results showed convincing evidence that the treatment of a plastic diet can allow these worms to adapt and increase the efficiency of their plastic consumption.

The Relationship Between Locus of Control and Recycling Behavior Amongst Youth

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In the field of psychology, *locus of control* is a commonly used term to define the degree to which individuals perceive an outcome as being influenced by external, uncontrollable factors, or their own actions and decisions. In past studies, those with external locus of control have been found to blame their environment for their failures rather than accepting responsibility. Some argue that external locus of control is used by some people to avoid responsibility and distance themselves from their misdeeds rather than making true efforts to solve a problem. This same argument could be placed on one's attitude towards recycling and the avoidance of guilt when one does not or cannot recycle. It was hypothesized that an individual with an internal locus of control is more likely to recycle than an individual with an external locus of control. To test this hypothesis, a 22-question survey was administered amongst an age group of 14-18 years old to identify sex, recycling frequency, recycling literacy, locus of control, and other personal characteristics/behaviors. The results found that those with a greater internal locus of control recycled more frequently (2.28x a week on average) than those with a greater external locus of control (1.02x a week on average). The results support the hypothesis and could be used to uncover methods of promoting recycling to improve the planet's health and nation's economy through marketing and sustainable productions of goods.

FLORIDA

Synthesis of Disulfide-Containing Polymeric Nanomedicine Carriers Suitable for Cysteamine and R848

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Teachers: Ms. Jennifer Gordinier and Mrs. Katherine Ganden, Pine Crest School
Research Advisors: Dr. Fuwu Zhang and Bowen Zhao, University of Miami

Current polymer-based nanomedicine carriers have several shortcomings regarding their efficacy: low drug loading capacity, premature drug release, poor in vivo monitoring capability, and limited accumulation in the targeted region. To address these shortcomings, my research investigates the use of disulfide-containing polymeric prodrug carriers. These polymer carriers self-assemble around the drug, encapsulating it, but contain disulfide cleavage links, which are cleaved and release cargo when glutathione (GSH) concentrations, a characteristic of the tumor microenvironment, is elevated. Two experimental carriers were synthesized: the homocysteine and terephthalic acid carriers, suitable for carrying cysteamine and R848, respectively. Cysteamine is a linear compound containing both amine and thiol groups, so designing a carrier capable of binding to cysteamine demonstrates its ability to bind other drug targets with similar properties. Additionally, R848 is a cyclic compound containing both amine and hydroxyl groups, so designing a carrier capable of binding to R848 demonstrates its ability to bind other drug targets with similar properties. Preliminary results regarding reaction purity and efficacy have been promising. H1-NMR spectra for each synthesis step have resulted in relatively pure samples, confirming the reaction and purification methods used. The reaction yields for the first three steps of the homocysteine projects were 62.7%, 58.7%, and 37.7%, respectively. The reaction yield for the first step of the terephthalic acid project was 22%. Although the yield values are relatively low, paired with the H1-NMR spectra, the results suggest that with minor modifications, the purity and efficiency of the reactions could be improved.

Analysis of the Microplastic Removal Efficiency of Synthesized Ferrofluids and the Development of an Automated Prototype for Aquatic Environments

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About 51 trillion microplastics (< 5mm size), which are known to be harmful to living organisms, are present in water bodies worldwide. Filters, membranes, and nets, currently used to capture aquatic microplastics are costly and labor-intensive, limiting widespread usage. Ferrofluids (Fe_3O_4 and oil) are cheaper alternatives, which exploit the hydrophobic properties of microplastics and oil, allowing microplastics removal using magnets. In this research, varying volumes of used and unused, cooking oils and engine oils were combined with varying weights of Fe_3O_4 to synthesize ferrofluids to extract fixed amounts of PP, PE, and PET (< 2mm sized) microplastics and the magnetic removal efficiencies (MRE) were calculated. The results were used to understand the effect of different oils, oil volume, and Fe_3O_4 weight on microplastic removal efficiency with the goal of reducing cost and negative environmental impacts. An electromechanical prototype using Raspberry Pi was built to fully automate microplastic removal. Results indicate an inverse relationship between oil volume and MRE. Unused cooking oil and used engine oil had the highest and lowest MRE, respectively. Greater than 85% average MRE was observed for each tested plastic using the prototype. Laboratory and prototype investigations indicate that a high MRE is possible, illustrating that ferrofluids used to magnetically remove microplastics are a viable solution to the increasing aquatic microplastics problem.

Predicting Recidivism with a Transparent Ensemble Machine Learning Algorithm

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America cycles 9 million people through jails and 600,000 through prison annually. Within three years of release, 66% of released individuals are re-arrested. Judges and officers use statistical risk assessment tools to gauge a defendant's odds of recidivating. However, such tools may contain bias. Two popular prediction algorithms, COMPAS and PATTERN, are criticized for over-predicting recidivism in Black and female defendants due to training with biased datasets. Misclassifications can produce widespread disparity. Defendants defined as medium/high risk are detained more often than low-risk defendants. Today, Black prisoners comprise 38% of incarcerated populations versus 13% of the general population, suggesting the concern is worth investigating.

This study compares COMPAS and PATTERN algorithms to an ensemble machine learning model built from three supervised learning processes for binary classification: logistic regression, random forest, and neural networks. Through dimensionality reduction and sensitivity analyses, the ensemble was evaluated using 41 factors (e.g., adult/juvenile criminal history, criminal charges, age, gender, and race) from a 7000-person public registry dataset of past criminal offenses. Results suggest a 7-factor ensemble model predicts recidivism as accurately as a 137-factor COMPAS and 63-factor PATTERN model with more transparency and fairness. Prior adult criminal history was the biggest driver of recidivism predictions, and dynamic criminogenic factors had minimal impact. A lack of bias on race or gender suggests the ensemble could be a suitable replacement for COMPAS and PATTERN algorithms. The study concludes that recidivism risk tools improve the equity and efficacy of predictions with careful attention to accuracy, fairness, and transparency.

Quorum Quenching Potential of Phytochemicals on *Chromobacterium violaceum Quorum* Sensing

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The purpose of this project was to evaluate the antibacterial potential of phytochemicals rutin, syringic acid, and *Ziziphus mucronata* extract on *Chromobacterium violaceum quorum* sensing. *Z. mucronata* extracts were imported from South Africa, then extracted in the lab; a SEM imaging series was conducted to evaluate for contamination and further develop a portfolio on it. The null hypothesis was if plant compounds are tested individually, then they will have similar efficiency as current antibiotics; the alternative hypothesis was if plant compounds are tested individually, then they will have greater efficiency than current antibiotics. While the alternative hypothesis was supported by comparing averages, not all of the results had a significant difference to the positive control. The three assays used in the experiment were swarming motility, violacein inhibition, and biofilm inhibition. Throughout the assays, *Z. mucronata* leaf, and bark extract had the strongest antimicrobial results: both performed statistically stronger than the positive control in at least one assay. In the violacein inhibition assay, *Z. mucronata* leaf extract had a statistically significant difference to the gentamicin. Additionally, *Z. mucronata* bark extract had a statistically stronger antibacterial effect to the gentamicin in regards to biofilm inhibition. The results of this project suggest that all of the plant compounds tested had possessed antimicrobial potential as they performed better than the negative control in most assays, but they did not consistently perform stronger than the positive control. The results of this project support the case to further expand on these phytochemicals from an antimicrobial standpoint.

Implementing A Hyper-Realistic Physics Engine in The Unity 3D Gaming Software in a Virtual-Reality Based Prosthetic Training & Baseline Tests

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Despite nearly 2 million people in the United States having an upper-arm amputation, 27- 56% of upper-body amputees use a prosthetic arm to regain limited mobility of their arm pre-amputation. 20% of prosthetic users abandon their prosthetic due to improper training and its lack of functionality. Current prosthetic training methods have additional limitations of being costly and restricts the user to a training or rehabilitative facility. Previous research has demonstrated greater accuracy and faster performance in tasks when a user was trained with virtual reality (VR).

The aim of this research is to develop a VR environment that can be used as a training platform for prosthetic users, as well as a baseline test for bidirectional sensory feedback. In order to make the virtual environment as realistic as possible, the external MuJoCo physics engine was incorporated into Unity development software to ensure that the physics in the virtual environment mimics the natural world.
The MuJoCo physics engine allows virtual objects to have realistic collision and contact events. My research focuses on optimizing MuJoCo so that it interfaces with the Unity gaming software and to attach its properties to game objects in the software. Incorporating MuJoCo physics resulted in game objects tested to have realistic sliding and rolling friction, gravitational forces, velocity and acceleration vectors, density and masses, as well as an ability to be "firm" or "soft". This re-engineered platform will allow us to conduct grasping and reaching tasks with a virtual, bi-directional neuroprosthesis.

Utilizing iPhone Haptic Feedback to Create Refreshable Braille

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The expensive nature and overall lack of braille resources has led to an extremely low braille literacy rate among the blind and visually impaired. Literacy in braille is the factor most correlated with employment and educational success of the blind, emphasizing the importance of developing this skill. This project seeks to develop a refreshable braille display using a smartphone's haptic feedback to represent "raised" braille cells that allows a user to input or scan text as a means to increase the availability of braille resources at an inexpensive cost. The testing performed after the construction of the app was to determine the most optimal settings for a visually impaired user. A combination of a 3D printed guide and heavy levels of haptic feedback were hypothesized to result in the most accurate readings by the user. These variables were tested separately after the app was coded in Swift using the XCode IDE. Random strings of 60 characters were generated and a box was used to obstruct vision, allowing for testing of the app. After the trials were concluded, the original hypothesis was deemed correct and resulted in high accuracy rates of 85% and 90%. This project will increase the equity of education and allow the visually impaired to learn the same literacy skills that are expected of those that are not

Optimization of Granular Locomotion Using Geometric Intruders

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Survey robots are vital to exploring extreme environments; however, limitations arise from the unpredictable nature of granular media. Currently, there is no model to characterize granular media interactions, making it difficult to explore. To address this issue, geometric intruders, similar to cleats, intruded and dragged through a fluidized testing bed filled with poppy seeds to see if at least one variable had a significant impact on granular force interactions. The variables intrusion distances of 1-3 centimeters (cm), intruder geometries of single-body and multi-body with spacings of 1-5 centimeters (cm), time delays between intrusion and drag movements of 100, 250, 2000 milliseconds (ms), and fluidized intrusion, and intruder materials of acrylonitrile butadiene styrene (ABS) and aluminum were tested. All variable permutations had three trials, and the maximum intrusion and drag forces were recorded in Newtons (N). Results showed that the 1 cm intrusion, single-body intruder, fluidized intrusion, and ABS intruder were more effective than their counterparts in reducing intrusion and drag forces. Also, fluidized intrusion reduced the drag force by 23.1% and ABS intruders reduced the intrusion force by 36.3% and the drag force by 21.1%, supporting the hypothesis and making it the most impactful in optimizing granular locomotion. It was also noticed that depending on the intruder material, intruder spacings of 4 cm and greater acted independently of one another when intruded at different distances, suggesting a new trend. Further investigation would be required to verify this with different materials.

Exploration of Novel Capsule Depolymerases from Bacteriophage to Combat Antibiotic Resistance in *Klebsiella pneumoniae*

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Mentor: Ky Lowenhaupt, Massachusetts Institute of Technology (MIT)

With the rapid rise of antibiotic resistance in bacteria, the fundamental need for new antimicrobial therapeutics is a pressing concern. In order to have an adequate arsenal to target antibiotic-resistant infections, innovative alternative treatment methods must be developed. One such area of interest is within bacteriophages, which are natural viruses that target and infect bacteria. These bacteriophages have evolved depolymerase enzymes capable of degrading the capsule of the bacteria and rendering it avirulent, forcing the bacteria to become non-pathogenic and unable to spread; it also allows for both the host immune system and antibiotics to be effective. In this research project, *Klebsiella pneumoniae* was targeted, a common multidrug-resistant pathogen responsible for at least 100,000 - 200,000 deaths per year. This project used the bacteriophage ϕKPNIH1-1—which was previously screened and isolated by our lab to target *K. pneumoniae*—and, based upon preliminary bioinformatic screening, successfully purified and characterized four possible depolymerase proteins. The strain and capsule specificity was tested, confirming the activity of three novel depolymerases. These proteins are specific and effective, making them appealing standalone or supplemental treatments for antibiotic-resistant infections and paving the way for future next-generation phage therapies. With a new era of antibiotic resistance rapidly approaching, this sort of emerging treatment holds great potential to enable a new class of antimicrobial therapeutics.

Identifying the Common Functions of Genes Linked to Autism Spectrum Disorder (ASD)

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Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder with a significant genetic contribution. Studies have identified hundreds of genes with evidence of involvement in ASD when mutated (“ASD genes”). Despite the vast number of ASD risk genes identified, our knowledge of these genes isn’t sufficient to use genetic information in ASD treatment or diagnosis in most cases. Due to the large number and diversity of ASD genes, I hypothesized that ASD genes share common functions in mammalian development. The functions of a gene can be determined by deleting (or “knocking out”) the gene in mice and observing the phenotype(s) that result. This study aimed to advance our understanding of ASD genetics by revealing common functions of ASD genes. To test my hypothesis, I performed bioinformatic and statistical analysis on a large collection of phenotyping data from the International Mouse Phenotyping Consortium (IMPC), which has cataloged 55,337 phenotypes that resulted from 7,093 gene knockouts in mice, including 395 orthologs of human ASD genes. I found that several phenotypes are significantly enriched among ASD gene knockouts relative to non-ASD gene knockouts. These phenotypes include embryonic lethality, increased thigmotaxis, hyperactivity, increased anxiety-related responses, decreased exploration in new environments, abnormal contextual conditioning behavior, increased circulating iron level, and increased lean body mass. The phenotypes identified here point to underlying developmental pathways and processes likely involved in the etiology of ASD and should be further studied. Furthermore, these results identify phenotypes that could be used to evaluate the validity of ASD mouse models used.

Novel Brain-Computer Interface for Binary Communication in Non-Verbal Patients Through Motor Imagery

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Speech and language are essential for social interactions and communication of medical problems. Patients with diseases such as ALS, locked-in syndrome, aphasia, and patients recovering from strokes are typically unable to communicate their basic needs to their doctors, resulting in low quality of life. The current best solution to this is Speech Generating Devices, which can often cost upwards of $15,000 and have an incredibly difficult learning curve. This study aims to design an easy-to-use and cost-effective brain-computer interface (BCI) using only 4 electrodes to aid those with nonverbal communication disorders. The BCI detects electrical signals related to left and right arm motor functions, corresponding to ‘yes’ or ‘no’ responses, allowing patients to imagine moving a certain arm to communicate this binary response without moving or speaking. The researchers developed a new novel preprocessing algorithm, the JMS Breakdown Algorithm, and found that the algorithm significantly outperforms other existing preprocessing algorithms in reducing classification errors and increasing information transfer rates. The novel use of an attention layer in the machine learning model also boosted classification accuracy by 4%, giving the machine a final classification error of 4.62% when tested at a set frequency of 11 Hz using both the JMS Breakdown Algorithm and the CNN-RNN with an attention layer, statistically lower than previous 4-electrode BCIs. The methods used in this paper can also be applied to BCIs of any use for improved accuracy, specifically the JMS Breakdown Algorithm, further enhancing the field of BCIs overall.

GREATER WASHINGTON, D.C.

Hybrid Plasticity: A Biologically Realistic Meta-Learning Algorithm to Increase the Adaptability and Efficiency of Artificial Intelligence Systems

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Mentor: Dr. Suraj Uaph, Triple Blind

Current Artificial Intelligence (AI) systems can learn arbitrarily complex patterns but struggle to generalize and adapt to new situations, making them unsuitable for real-world deployment. Therefore, I propose Hybrid Learning (HL), a meta-learning rule that allows AI to learn and remember new concepts. HL is a mathematical rule I derived to mimic prefrontal plasticity, imitating the brain's information coding and retention process. During training, synapse-specific HL coefficients are learned that allows the network weights to use environmental input to guide convergence to a set of optimal weights as governed by an attractor in the weight-phase-space. I test HL on artificial neural networks (ANN), completing OpenAI reinforcement learning (RL) tasks, and recurrent neural networks (RNN) completing complex memory tasks. HL significantly outperforms many standard RL approaches, including Proximal Policy Optimization and Deep Q-Learning, while simultaneously increasing the adaptability of ANNs significantly more than other meta-learning approaches, including Hebbian Learning. Furthermore, in RNNs, HL significantly increases adaptability and performance while reproducing neurobiological phenomena within network connectivity. HL networks exhibit close mimicry of GABAergic circuits, as they start unorganized but self-organize into inhibitory and excitatory clusters, develop strong inhibitory autapses, and demonstrate high levels of efficiency, parallel processing, and cognitive integration. These findings provide evidence for two neuroscientific theories, the Synaptic Theory of Working Memory and the Global Workspace Theory of Consciousness. Experimentation indicates that HL is a state-of-the-art meta-learning algorithm that increases the performance and generalizability of AI systems while also acting as a tool to study the brain using artificial networks.

StrokeSight: An Intelligent EEG-Based Approach to Rapid Stroke Diagnosis Using Spectral Biomarkers towards Precision Medicine Approaches

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A stroke is defined as a neurologic deficit arising from an interruption in blood supply to the brain. According to the World Health Organization, over 15 million people suffer from strokes annually, of which almost 70% die or are permanently disabled. Effective treatment must be administered within one hour to prevent irreversible brain damage. Currently, there is no cost-effective, fast, and portable diagnostic tool for strokes. This research proposes StrokeSight, a novel pipeline that provides a comprehensive assessment of ischemic and hemorrhagic strokes in under 50 seconds using electroencephalograms (EEGs). Spectral biomarkers were computed using the averaged power spectral densities for 132, 60-second EEG readings. One-way ANOVA tests validated the effectiveness of such biomarkers for stroke classification. These were first used to train three deep neural networks that respectively predict a stroke's type (none/ischemic/hemorrhagic), location (left/right hemisphere), and severity (small/large) with accuracies of 97.5%, 94.4%, and 100%. StrokeSight also uses these biomarkers in a novel process to visualize spectral abnormalities caused by strokes. Azimuthal equidistant projection and multivariate spline interpolation are used to project 3D electrodes onto a 2D plane, and a contour map of relative frequency band power is created, allowing neurologists to quickly and accurately interpret EEG data. StrokeSight could drastically improve the speed and accessibility of stroke diagnosis by making EEG-based diagnosis more cost-effective and easier to interpret. This research also sets up the potential for precision medicine approaches to stroke treatment by automating comprehensive analyses of strokes.

BOREAS: Innovating Respiratory Care with Telemedicine

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Telemedicine, as a revolutionary innovation, has the potential to remedy healthcare disparities on a global scale. The COVID-19 pandemic has facilitated the adoption of telemedicine as the primary mode of care for medical consultations in the United States, particularly for the diagnosis of respiratory diseases. However, a significant limitation of telemedicine is its inability to transmit breath sounds, a crucial clinical data metric, essential for the effective diagnosis of respiratory diseases. After extensive brainstorming, research and consultation with physicians, I conceptualized and designed BOREAS- an integrated hardware-software solution that can capture and transmit breath sounds, optimized for telemedicine.

A prototype for BOREAS was built, consisting of a lapel microphone capture device and a smartphone app that utilizes a Javascript-based framework. It was designed, built, and tested using multiple breath sound libraries. The results of the waveform analysis of the transmitted breath sounds via the BOREAS platform revealed a high level of accuracy. Furthermore, the integration of machine learning, utilizing the 3M Littmann Library data enabled the recognition of breath sound patterns, thus validating the efficacy of the BOREAS platform and facilitating the rapid and accurate diagnosis of respiratory diseases. In summary, this integrated hardware-software solution can capture and transmit breath sounds, a crucial diagnostic parameter that is lacking in existing telemedicine solutions. It holds the potential to significantly improve healthcare delivery and reduce the morbidity/mortality associated with respiratory diseases, helping millions of patients worldwide.

SPOTCPC: A Novel Approach to COVID-19 Prediction Utilizing Human Mobility Data and Contrastive Predictive Coding

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During the COVID-19 pandemic, time series prediction models have been essential in informing policymaking and response efforts by forecasting cases and deaths from the country to county levels. However, the emergence of new COVID-19 variants presents challenges for existing models, which may not account for previously unseen disease trends. Furthermore, several models fail to incorporate covariate features, such as human mobility data, which could enhance model accuracy due to their correlation with COVID-19 spread. To address these challenges, we propose SPOTCPC (Spatial PrObabilisTic Contrastive Predictive Coding), which augments CPC by incorporating a mobility matrix that represents the relative number of individuals traveling between each county on a given day into the model's loss function. The Metropolis-Hastings algorithm then samples the proposal distribution learned by this component of SPOTCPC to provide a final prediction of the number of COVID-19 cases in each region. Our experiments show that SPOTCPC can make accurate short-term predictions, which are more accurate than ARIMA and other time-series extrapolation methods, one day into the future. We also find that the SPOTCPC outputs for prediction windows seven or more days into the future are comparable to those provided by existing models.

Bioinspired Fish Propulsion for Unmanned Underwater Vehicles: A Novel Movement and Design Algorithm Using Constraint-Guided Models to Predict Kinematic Gait Outcomes

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Unmanned underwater vehicles (UUVs) require greater maneuverability and propulsive efficiency to meet the design requirements for an expanding envelope of operations such as researching vast unexplored depths or military surveillance in ports and vessel tracking. A potential solution to these growing needs lies in biomimicry, a field that has garnered attention from researchers who believe that the biological designs of marine animals, who swim with high propulsive efficiency and maneuverability, offer tremendous potential for improving the efficiency of UUV designs. Fish pectoral fins have emerged as a frontrunner in research due to the agility they enable over traditional systems. Previous studies have explored ways to replicate fish fins in robotic design, and led to optimizations for fin structure, thrust generation, and material choices, but there is little known work done on optimizing power consumption and, consequently, efficiency. To resolve this gap in the literature, this study developed a non-dimensional figure of merit (FOM), derived from measures of propulsive efficiency, allowing researchers to evaluate the efficiency of different fin designs and movements, and allow for comparison with other bio-inspired platforms. My research resulted in the creation of practical computational ML models constrained by system power and time to output the most efficient move and predict thrust and power under different fin operating states, providing efficiency profiles for movements and designs with 0.09% average error. The newly developed FOM was utilized to analyze optimal gaits and compare the performance between different fin materials, recommending materials and gait patterns for further study.

HAWAII AND PACIFIC

Antipodal Algae: Energy Solutions for a Tropical Island

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As the emission of carbon dioxide into our atmosphere continues to contribute to climate change, the search for a cleaner energy source prevails. Using algae as a biofuel can replace our use of diesel fuel in American Samoa because algae is both naturally abundant and grows at a fast rate. Algal biofuel is also a very promising fossil fuel replacement due to algae's high levels of lipids which can be extracted efficiently without the use of dangerous chemicals.

American Samoa has the ideal climate to grow and harvest algae as biofuel. Applying experimental methods I learned at a biotechnology course at UC Berkeley, I was able to extract algal lipids and convert them into biofuel using the local resources found on our island such as coconuts. After harvesting and growing three of the most abundant algal sources on Tutuila, I measured the mass of each algae species and observed that *Mougeotia scalaris*, the ocean algae, reproduces faster than freshwater algae. To test which species contains the most lipids, I lysed my *Callithamnion* and *Filamentous* algae with a potassium iodide solution I made from coconut ash and found that Filamentous algae produces the most algal biofuel. In this project, I was able to convert algae into algal biofuel using local resources and discovered what species could potentially replace our fuel source in American Samoa.

Potential Use of MicroRNA-488 as a Biomarker for Type 2 Diabetes

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Type 2 Diabetes (T2D) affects millions worldwide but has an exceptionally high prevalence in Hawaii, with a rate of 9% for all residents aged 18 or older. Of that 9%, 13.1% are Native Hawaiians, and 23.0% are other Pacific Islanders, demonstrating a high degree of health disparity in Hawaii. This study aims to amend this issue by finding a biomarker to predict the bad prognosis of T2D. Such a biomarker, coupled with traditional therapeutic strategies, could help prevent the pathogenesis of the disease.

Previous limited methylation data in monocytes from Dr. Maunakea's lab indicated that microRNA-488 (miR-488) could be a biomarker since its promoter was hypomethylated in diabetic patients. High concentrations of miR-488 have been linked to diabetic nephropathy, one of the most serious complications of diabetes. In this project, we increased our methylation sample number in the study, performing microarray analysis on an additional 96 patient samples. Methylation analysis confirmed the change in the promoter of miRNA-488. We extended our analysis by investigating the microRNA expression in the monocytes using RT-qPCR. The results indicated that both miR-488-3p and miR-488-5p are significantly upregulated in the monocytes of T2D patients.

Our data show that miR-488 is significantly upregulated in T2D patients due to changes in promoter methylation. This change caused by the disease could cause more complications, including diabetic nephropathy. Next, we intend to check the expression of the miRNA of patients at different stages of the disease to further characterize its time course.

Studies on *Gracilaria salicornia*: Zinc Oxide (ZnO) Sunscreen Exposure and Use as Agricultural Fertilizer

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Limu (seaweed) is critical to Native Hawaiian ecosystems and culture. With limited prior research, the first part of this study examined the effects of ZnO mineral sunscreens on endemic Hawaiian *Gracilaria coronopifolia* (Limu Manauea) and invasive *Gracilaria salicornia* (Gorilla Ogo). For three months, samples were measured twice weekly for length and apical tip counts. ZnO had a more negative effect on the percent change in length and apical tip count of the endemic *G. coronopifolia* than the invasive *G. salicornia*. Due to the invasive *G. salicornia* being so abundant in Hawaiian ecosystems, for the second part of the study, four fertilizers were developed: two created from fermented *G. salicornia*: 10% and 25% concentrations, two from desiccated *G. salicornia*:1.0% and 2.5% concentrations. Corn, green bean, and romaine lettuce seeds were treated and observed (number germinated and radicle length of germinated seeds). The 10% liquid fertilizer was found to significantly increase the radicle length of all tested seeds, while the 2.5% dry fertilizer had detrimental effects. In the final experiment, where broccoli plants were used rather than plant seeds, two additional fertilizers (1.0% GF and 2.0% GF) were composed of desiccated *G. salicornia* as an improvement to the dry fertilizers. The 10% liquid fertilizer again increased growth of the broccoli plants when compared to the control. Future research is necessary to determine the biochemical basis for the contrast in outcomes between the liquid vs. dried/gel fertilizers, which could provide new insights into fertilizer development.

Lower pH Levels Negatively Affect *Tripneustes gratilla* Fertilization and Development

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As human carbon dioxide emissions dissolve in the ocean, the pH of the ocean drops in the natural phenomenon known as ocean acidification (Brewer 2013). In 2100, the ocean's pH is predicted to be 7.6 (NOAA Ocean

Acidification Steering Committee). Testing on urchin gametes is a possible method of concluding whether or not other sea urchins and other organisms can survive in a given water quality (Dinnel 1989). The sea urchin *Tripneustes gratilla* is often used as an indicator of water habitability due to its sensitivity to water quality. This study used *T. gratilla* eggs to measure fertilization rates in different pH levels. Eggs were fertilized in different pH levels, ranging from pH 8.3 (a healthy ocean pH) to pH 7.6 (the pH level predicted to be in 2100). Successfully fertilized eggs were counted after 40 minutes. The hypothesis that fertilization success would be low at a pH of 7.6 was reflected by the data. Lower pH levels were also harmful to sperm motility and stumped embryo development but had no effect on egg viability. Results suggest that lower pH levels significantly negatively impact *T. gratilla* fertilization and development rates. Therefore *T. gratilla* and many other species may be at risk in the future, due to projected lower pH levels.

Identifying the Molecular Mechanisms of a Safer Neuroblastoma Cure Using the Native Hawaiian ʻAwapuhi *(Zingiber zerumbet)* Herb

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Neuroblastoma one of the most severe tumors in young children with nearly 500 new cases reported each year. Currently, the only treatments available for this cancer are chemotherapy and radiation therapy, both of which have detrimental side effects. As a result, there is an urgent demand for an effective yet safer anticancer reagent. In light of recent research, natural products derived from plants have been shown to be more tolerable anticancer reagents. Hawaiʻi is a place of exceptionally rich traditional medicinal knowledge with traditional healers often using a variety of Hawaiʻi's herbs for disease treatment. However, due to the lack of research on these herbs' effects and molecular mechanisms, much of this potential remains unrealized. Thus, this project aims to quantitatively analyze the effects of traditional Hawaiian herbal medicine and apply this knowledge into modern applications such as cancer treatment. Through a literature screening, Z*ingiber zerumbet* (ʻawapuhi) was found to be a promising candidate for anticancer research due to its prominent usage in native Hawaiian medicine. However, *Zingiber zerumbet's* effects on neuroblastoma have not been researched and more importantly, its detailed molecular mechanisms remain undiscovered, greatly hindering the development of a promising anticancer reagent. Here, the anticancer activity of *Zingiber zerumbet* on neuroblastoma was found to be significantly safer, yet just as effective, compared to conventional chemotherapy. Furthermore, a novel antioxidant-mediated molecular mechanism was identified and refined. Elucidating the anticancer mechanisms of *Zingiber zerumbet*, this research will be able to provide valuable information for the future design safer anticancer drugs.

ILLINOIS-CHICAGO

Predicting Large Wildfires Using Machine Learning Approach towards Environmental Justice via Remote Sensing

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Wildfires pose severe health and ecological consequences. In 2021 alone, 58,968 wildfires burned 7.1 million acres across the United States. Large wildfires (> 300 acres) in the United States, account for more than 95% of the burned area in a given year. Predicting large wildfires is imperative, however, current wildfire predictive models are localized and computationally expensive. My research aims to accurately predict large wildfire occurrences across the United States based on easily available environmental data and using a scalable model.

The USDA data for 1326 wildfire occurrences over 20 years, representing 35 million acres burned, and

NASA MODIS remote sensing data consisting of 925 million satellite observations were used. First, six key environmental variables were identified and annual averages over three years leading up to each wildfire occurrence were computed. Next, the resulting dataset of 18 environmental variables was tested on six different machine learning classification models (Logistic Regression, Decision Tree, Random Forest, XGBoost, KNN, and SVM) to determine their accuracy in predicting large wildfires. Finally, model validation tests and permutation feature importance analysis to identify important variables was performed.

The XGBoost Classification model performed the best in predicting large wildfires, with an accuracy of 87.81%. Furthermore, towards Environmental Justice (Justice40 Initiative), an analysis was performed to identify disadvantaged communities that are also vulnerable to large wildfire occurrences. My model can be used by wildfire safety organizations to predict large wildfire occurrences with high accuracy and employ protective safeguards to prioritize resource allocation for socioeconomically disadvantaged communities.

Space-Time Conflict Spheres for Constrained Multi-Agent Motion Planning

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1.3 million people are killed in road accidents each year, and 94% of these accidents are caused by human error. This has motivated advancements in autonomous vehicle technology, and more recently, connected autonomous vehicles (CAVs). CAVs communicate location and intention information with each other over the air, and the prospect of cooperative planning within a system of CAVs promises greater safety and efficiency in travel. CAV cooperative planning can be formulated as multi-agent motion planning (MAMP), and we propose a space-time conflict resolution approach for MAMP. We formulate the problem using a novel, flexible sphere-based trajectory representation. We then compose discrete-time procedures while evading discretization error and adhering to kinematic constraints in generated solutions. Theoretically, we prove the continuous-time feasibility and formulation-space completeness of our algorithm. Experimentally, we demonstrate that our algorithm matches the performance of the current state of the art with respect to runtime and solution quality, while expanding upon the abilities of current work through accommodation for both static and dynamic obstacles. We evaluate our algorithm in various unsignalized traffic intersection scenarios using CARLA, an open-source vehicle simulator. Results show significant success rate improvement in spatially constrained settings and performance that scales well among increasingly complex scenarios. From its contributions, we claim that our algorithm is the first CAV coordination strategy to enable provably safe motion planning among pedestrians and human-operated vehicles.

The Effect of a Novel Biomedical Technique on the Reprocessing of Biofilm-Contaminated Duodenoscopes Using Copper Sulfate and Methylene Blue Irradiated with Red Light

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Endoscopy-related infections are becoming increasingly prevalent and harder to prevent in the era of increasing multidrug-resistant bacteria. Bacteria are developing resistance to bactericides at an unprecedented rate which is a growing problem in the medical field, especially in remote areas with limited resources such as military zones and field hospitals. Duodenoscopes, notably difficult to sterilize due to their intricate elevator component known to harbor bacteria that often form biofilms, frequently resulting in post-operative infections. This experiment contained 7 groups where model duodenoscopes were contaminated with *P. fluorescens* biofilms (modeling *P. aeruginosa*) and were exposed to a novel treatment consisting of varying concentrations of copper sulfate and methylene blue solutions irradiated with red light to determine the bactericidal effects. There was a positive and negative control group as well as three experimental groups that each had varying concentrations of the combination solution. Additionally, there were two groups using each chemical alone. It was hypothesized that the combination of copper sulfate and methylene blue would produce the greatest bactericidal effect. Biofilms were formed on the model duodenoscopes and the copper sulfate and methylene blue solutions were applied and irradiated with red light. The models were then swabbed and absorbances were tested using a spectrophotometer at 600 nm to compare the amounts of live bacteria. This novel treatment has potential to be a bactericide and effectively eliminate a significant amount of bacteria within biofilms and that there is a possible synergy exhibited when the chemicals are combined. All five experimental groups demonstrated bactericidal.

Vulnerability of Communication-Free Virtual Oscillator Controlled Next-Generation Grid Forming Inverters to Cyberattacks and its Mitigation

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Electric grid is rapidly transitioning from fossil-fuel-based centralized generation to inverter-based renewable-energy distributed generation. This necessitates the *synchronized* operation of a multitude of such inverters, which is growing exponentially with larger penetration of renewables, to prevent grid instability. Such synchronism is achieved conventionally using a communication-based coordination. In contrast, in virtual-oscillator-control-(VOC)-based grid-forming (GF) communication-free *self-synchronizing* inverters (CFSIs), no such inter-inverter communication is required. Hence, such inverters have gained traction because they enable decentralized operation and “apparently” reduce vulnerability to cyberattacks.

While the VOC-based GF CFSIs preclude the need for inter-inverter data communication, each inverter is nonetheless self-synchronously coupled to the 60-Hz power grid and exchange energy over it that couples the CFSIs. This implies that, if the synchronism of even one VOC-based GF CFSI is affected, then, it compromises the synchronism/stability of the entire multi-CFSI power network.

The VOC-based GF CFSI control relies on locally-sensed grid information. If this local information is tampered using side-channel noise intrusion (SNI), it may affect the synchronism of that CFSI and then propagate to other CFSIs over the network. Hence, in this research, we specifically investigate experimentally and theoretically the effect of SNI on the ability of a VOC-based GF CFSI to ensure a stable 60-Hz limit cycle and explore the impact of SNI on the parallel operation of such CFSIs to ensure synchronism to a common 60-Hz load frequency. Finally, we pursue a Kalman-filter estimation based pathway for mitigating the negative impacts of SNI on the CFSI dynamics and assessing its efficacy experimentally.

Novel Probiotic Treatment for Candida albicans Utilizing Antifungal Inhibitors of Lactobacillus acidophilus via a Bombyx mori Infection Model

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Candidiasis refers to various infections attributable to the opportunistic yeast fungus Candida. These infections possess the ability to manifest in various forms specific to the location of colonization, and are capable of inducing bacterial endocarditis, candidemic septic shock, infections of the bloodstream, and in severe cases- death. One of the most prevalent strains of *Candida* is *Candida albicans* of the *Saccharomycetaceae* family. *C.albicans* has developed multidrug resistance due to the overuse of common candidiasis treatments such as itraconazole, fluconazole, and amphotericin B. This experiment identified and tested a novel probiotic treatment sourced from live *Lactobacillus acidophilus* to combat the increasing multidrug resistance of the *C.albicans* strain without compromising the effectiveness of candidiasis inhibition. A *Bombyx mori* infection model was used to host this interaction through induced candidiasis infection and direct injection of the novel treatment. The results of this experiment display a significant reduction in the pathogenicity of *C.albicans* infection with an 80% increase in the chance of survival after treatment (Chi-Square p= <0.0001). This demonstrates promise for potential utilization in medicinal development to address the rising concern of mortality rates associated with the increase in fungal infections.

ILLINOIS

Simulating Embryonic Development in Vitro Using Embryoid Bodies

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During the developmental stages of mammalian embryos, the inner cell mass (ICM) gives rise to all embryonic tissues. The ICM, when adapted to in vitro culture, becomes embryonic stem cells (ESCs). These pluripotent ESCs are capable of differentiating into all three germ-layers. The purpose of the investigation is to reinitiate embryonic development in vitro using a mouse reporter ESC line and to observe self-organization of the germ-layers. The reporter ESCs express yellow fluorescent protein when the mesoderm (one of the germ-layers) specific gene, Brachyury, is activated. ESCs are often cultured into 3D cell aggregates which mimic the traits of early embryonic development, called embryoid bodies (EBs). Here, two methods were used to generate EBs- the hanging drop culture and Aggrewell 400 plates. In hanging drop culture, ESC containing droplets were dispensed onto the underside of a lid of a tissue culture plate and flipped over so that the droplets were suspended over water to prevent evaporation. After 4 days, the EBs were collected and counted. In comparison, for the Aggrewell 400 plates, an anti-adherence solution was coated and rinsed off before adding cells to each one of the 24 wells. After 4 days, EBs were counted. EBs from both methods were imaged using an inverted epifluorescence widefield microscope and the images were processed using the ImageJ software. Based on this investigation, the hanging drop culture method generated more spherical EBs and allowed for mesoderm germ-layer to be organized “in the middle” of the EBs compared to the Aggrewell 400 plates.

Integrating 3D Printing into Titanium Dioxide Nanotube Fabrication

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Titanium dioxide nanotubes (TiO_2 NTs) have numerous biomedical, photocatalytic, and optical properties. However, a noticeable trend in the literature is the absence of electrode spacing parameters. Fortunately, this confounding variable can be eliminated with the usage of 3D printing and CAD. By integrating materials chemistry and rapid prototyping, unspecified parameters can be standardized by means of a 3D printed anodization guide. Herein, several nanotube growth guides were fabricated and tested within an electrolytic cell to evaluate their effectiveness and region-dependent growth trends. Observational characterization demonstrates that TiO_2 NTs were observed to grow longer and with wider diameters at areas closer to the opposite electrode while others grew shorter and had smaller diameters at farther areas. These data informed a transitional approach to implementing the templates in the direct synthesis of TiO_2 nanotubes on conductive FTO glass. The results from this testing show novel growth patterns and allow for future improvements for facile syntheses of TiO_2 NTs on various surfaces. We conclude that this demonstrates the versatility and usability of 3D printing in the laboratory as a response to certain reaction conditions.

Calculation and Comparison of Star Formation within the Pinwheel Galaxy

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The relationship consistency between nine different methods of calculating star formation on galactic scales was investigated. These methods varied in approach. Five methods were based on emission and four were based on other galactic factors. From various sources, it was assumed that there was a large discrepancy between any methods used due to the large amounts of variation inherent to observational data. Galactic data regarding the Pinwheel Galaxy (M101) and a number of star formation rate formulas was gathered from various sources. This data was then used to calculate the star formation rate of the galaxy M101 using the 9 methods. The resulting rates were plotted onto scatter plots and the lack of an observed relationship was noted. The hypothesis had evidence which supported it as a lack of a relationship between any of the points was obvious, and numerically they varied over 10 orders of magnitude. It is likely that this is due to the inherent variability of observational data on galactic scales and large scale intergalactic dust obscurity.

Supervised Binary Convolutional Neural Networks with Model Stacking for Diagnosis of Fundus & Eyelid Diseases

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Retinal health is often overlooked and seen as a privilege, not a necessity. Although there are a variety of machine learning-based solutions and retinal specialists to diagnose these ailments, they require expensive equipment and resources, and oftentimes overlook specific retinal diseases.
The following comprehensive paper details the creation of six binary convolutional neural networks to diagnose Diabetic Retinopathy, Age-Related Macular Degeneration, Myopia, Glaucoma, Ocular Hypertension, and Cataracts with fundus images, along with a seventh Trachoma neural network through inner under eyelid images. To produce a conclusive diagnosis, model stacking was implemented, and the classification results were compared to a trial multi-classification neural network. Analysis was also completed on the sklearn test data reports and confusion matrixes for the test dataset. The neural networks produced promising results for both training (90% +) and testing data accuracies (65% +) along with model classification and have the ability to identify new features in the fundus image.

After analyzing the convolutions, it was found that the models were focusing on the optic disc and fovea region of the fundus along with pigmentation and fundus spots, often overlooked with traditional diagnosis. Additionally, the Trachoma CNN may be able to provide further insights into what specific features of the inner eyelid to focus on when diagnosing this ailment. Traditionally, inner eyelid scarring and magnitude of the puss are used. However, the feature maps depict that pigmentation of eyelid scarring along with puss, eyelash rheum, and trichiasis [abnormal unhealthy eyelash placement] in the inner eyelid were fixated on.

Uranium-238 Decay Through Lead Contamination in Coldwater Creek, MO

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Coldwater Creek, MO was radiologically contaminated in the late 1960s posing significant 238-Uranium decay risk to locals. After the Love Canal disaster, the Environmental Protection Agency (EPA) requires five-year reports to be done on all National Priorities List (NPL) sites. The creek is designated as a site on the NPL by the EPA. The goal of this research was to calculate the concentration of lead in Coldwater Creek over six weeks. If the water from Coldwater Creek is analyzed, then the concentration of lead in the creek will be 15 ppb or greater. The samples were collected every other week for a total of three trials, sample testing commenced the next day. All testing and analysis of samples took place at Edwardsville High School, Edwardsville IL. JNW Heavy Metal Testing Strips were used to test the water for mercury, lead, copper, and iron. Mercury and Iron had 0 ppm in all of the samples. Copper averaged at .66 ppm. The hypothetical concentration of 15 ppb was undershot by 22.2 percent at 11.66 ppb. The underrepresentation of lead ions in the water indicated an absence of 238-Uranium within the water samples, alluding to uranium diffusing into other portions of the environment. This diffusion requires further testing of other environmental factors like tree roots and soil sediments. Through dissemination and routine testing, contaminant information can be dispersed to locals located in St. Louis County along with many other NPL locations across the United States.

INDIANA

Machine-Learning-Based Identification of Cognitive Engagement States In EEG Data Driven By Visual Stimulation

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Monitoring cognitive engagement and comprehension may prevent accidents and save lives, especially with drivers of autonomous vehicles, air traffic controllers, and in other attention-critical situations. However, there is currently no passive monitoring capable of determining a person's cognitive engagement with the world around them.

This project assesses the possibility of detecting the cognitive engagement state (comprehension) of a person based on the frequency following response of the brain to motion. Electroencephalography (EEG) data of deaf singers and hearing non-signers watching two sets of videos was used. Set one showed a signer producing sentences (normal human motion, comprehensible to native signers); set two contained the same videos played in reverse (abnormal motion, incomprehensible to both groups). The peak correlation between the subject's EEG signal and the video's motion (amplitude, timing, brain-region) was passed into a variety of machine learning (ML) algorithms which were trained to identify the subject (signer versus non-signer) and their cognitive state (understanding/normal versus abnormal). Feature analysis was used to optimize performance and to characterize the neurophysiological response.

Identification of signers observing sign language (2-state classification) was 100% accurate. 4-state classification (2 groups x 2 sets) yielded above-chance performance (77%). Based on feature importance, both populations engage in predictive processing of human motion, but signer's alpha frequency engages earlier with executive and language regions of the brain than with non-signers. These findings demonstrate that ML analysis using only the EEG-based frequency-following-response to visual stimuli can be effectively used to identify higher cognitive engagement and to monitor operator understanding.

Microstructural Evolution of Coffee Beans by High Resolution X-ray Microscopy

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Coffee has become one of the most popular beverages world-wide. But how is coffee made? Coffee beans can be studied to generate new, more effective methods to crush the beans. I studied and took images of different types of coffee beans from Colombia and Ethiopia before they were roasted and after they were roasted using x-ray microtomography. Using the images generated from the microtomography, the differences in microstructure of the coffee bean were studied before and after the roasting process. The heat involved in the roasting process led to a substantial development of pores forming after the bean was roasted. It was discovered that the heat increased size of the pores of the bean, leading to the Volume Fraction of Porosity (%), changing from 5% to 28% in the Colombian Bean, and to 36% in the Ethiopian Bean. Since the Ethiopian Bean was grown at a higher altitude, it had less moisture, likely resulting in larger pore sizes after the roasting process. Since the Ethiopian Bean has less moisture due to the higher altitude of growth, more pores were seen in the bean compared to the Colombian Bean. The aspect ratio of the pores and the diameter distribution were calculated and are discussed.

Investigating the Effect of Plastic Mulches on Agroinfiltration

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Agroinfiltration, a simple and efficient method to transiently express recombinant proteins in plants using Agrobacterium bacteria, is a popular method for biological research. However, few studies have tried to increase the efficiency of the process. This project aims to raise the efficiency of agroinfiltration in Nicotiana benthamiana using colored plastic mulches which have been found to increase plant growth by affecting plant conditions like the soil or light. Four groups of plants were investigated: a control without any plastic coverings on plants, red plastic, black plastic, and silver plastic mulch covered groups. A RUBY reporter was used to express the red pigment betalain via agroinfiltration. The concentration of betalain pigment was measured with spectrophotometry. A two sample t-test showed a significant difference between having plastic mulch versus not having any. Therefore, there was evidence that plastic mulches made a difference in agroinfiltration efficiency.

Identification of Pancreatic Cancer Driver Genes with a Novel Machine Learning Approach: Principal Features

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With the lowest 5-year survival rate among all cancers, pancreatic cancer is considered one of the most lethal diseases in the world. Currently, there are very few reliable genes to target in pancreatic cancer therapies; hence, identifying new biomarkers is crucially needed. This study develops a state-of-the-art machine-learning workflow for cancer biomarker discovery: first, we detect the cancerous gene expression patterns through random forest modeling of the principal components of the single-cell RNA-sequencing (scRNA-seq) data and then second, we identify the key genes driving these patterns. This method accounts for the effects of complex gene-gene interactions through random forest modeling and, thus, enables the genes driving cancer cell growth to be accurately identified. With a scRNA-seq dataset of pancreatic cancer, our workflow identifies several genes, including KRT17 and PTGS2, which have been validated as potential therapeutic targets in the literature. Our workflow also identifies novel genes that have never been studied, including MXRA5 and NDUFA6, while showing great potential as therapeutic targets. Their overexpression is linked with inferior survival in pancreatic cancer patients. My workflow potentially accelerates discoveries of therapeutic targets for genetic diseases, and for pancreatic cancer, my newly-discovered genes provide promising directions for advancing its treatments.

The Trends in Music and Technology: Prospectives and Approaches for Early Childhood Development

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Teacher: Allison Malloy, Carmel High School

Film, a key medium for early childhood development, utilizes musical and technical aspects to convey emotions to a young audience. While past studies have established the importance of music for emotional cognizance in children, over the last century, technical innovations have drastically changed the production methods of children's films, shifting the methods for emotional conveyal and their relative efficacies. This study collected and analyzed data from musically relevant animated children's films over the last century to identify the reliance on musical and technical aspects to convey emotions during emotional turning points. One film was chosen from each decade, 1930-2020, and scored for musical and technical aspect usage during five emotional turning points. A codebook was created to quantify the use of six musical and six technical aspects of film during emotional turning points. Data was analyzed using Python modules to visualize trend behavior through linear regression models. Findings indicated a decreased reliance on musical aspects and an increased reliance on technical aspects over time to convey emotions. A negative sloping trendline was identified for the musical to technical score ratio over time with $p<.001$. The effects of decreased musical reliance in films and the relative efficacy of technical aspects for emotional conveyal must be further studied. Utilizing the codebook and foundational automation mechanism, musical and technical reliance levels in the modern film-centered ecosystem can be further studied, thus instilling a foundation for the future and impact of music and film therapy for early childhood development.

INTERMOUNTAIN

Purification of the MED1 Receptor Interaction Domain

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Mentor: Michelle Nemetchek

A class of type II diabetes medication interacts with a nuclear receptor known as PPARγ. While these drugs are effective at managing type II diabetes, however, they have dangerous side effects including heart failure. One way to improve these pharmaceutical drugs is to understand how PPARγ controls the transcription of anti-diabetic genes through interacting with the coregulator MED1. Because MED1 is an intrinsically disordered protein, which makes it difficult to purify and study, research on MED1 has been minimal in current literature and only uses a small domain of the entire protein. We hypothesized that larger portions of MED1 would encompass more binding sites and thus have a higher affinity for PPARγ. To test this hypothesis, we screened various portions of the MED1 protein to determine the impact of size, growth conditions, and purification methods on protein purity when expressed in *E. coli* cells. These optimized protocols were then implemented in a final trial to compare the effect that the length of MED1 has on the binding affinity of MED1 to PPARγ. This trial provided data that longer regions of MED1 do bind tighter to PPARγ, supporting the hypothesis that domains outside the main interacting region of MED1 contribute to binding. Studying this interaction will lead to a better

understanding of how current pharmaceutical drugs behave, and how they can be improved to have fewer side effects.

DiSCoVeR: an Attention and Density-based Machine Learning Algorithm for Discovering Novel Superhard Materials

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Mentor: Professor Taylor Sparks, Materials Science & Engineering Department at the University of Utah

Superhard materials are crucial in a host of modern technology industries from construction to transportation, medicine, and energy. While diamond is currently the hardest known material, its high cost makes it impractical for mass industrial applications, necessitating a more abundant and cheaper material.

The Descending from Stochastic Clustering Variance Regression algorithm (DiSCoVeR) is presented in this research: a machine learning (ML) framework that combines four computational data and ML methods to discover novel superhard materials.

The project was divided into four phases. First, hyperparameter optimization is performed on CrabNet, an attention-based ML algorithm that makes materials property predictions and part of DiSCoVeR, and state-of-the-art performance is achieved. DiSCoVeR is then used to screen ~70,000 compounds for superhard materials. Next, three of the top candidates ($CrBMo_2$, $Cr_{22}MoC_6$, and $Cr_{21}(WC_3)_2$) are synthesized and their hardness measured to experimentally validate DiSCoVeR. All three candidates exhibited significantly higher Vickers hardness than any hard materials used in industry today. In the final phase, DiSCoVeR is employed to discover new superhard materials from over 7 million unique candidates and 11 million calculations, including completely theoretical compounds never synthesized before. It finds several candidates predicted to have a higher bulk modulus than diamond.
This research is the first time an automated screening method is created and performed with special emphasis on high-performing, novel materials. Not only is DiSCoVeR proven to be effective at screening for superhard materials, but it has enormous potential for discovering high-performance materials of other properties as well.

Assessing Aeration Methods for Remediation of Hydrocarbon Contaminated Soil

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Teacher: Amanda Nix, North Toole County High School

In Montana, over 150,000 acres of public land have been contaminated by hydrocarbons. These areas are more susceptible to groundwater contamination and climate issues. I chose this investigation because if remediation of hydrocarbon contaminated soils could be achieved through aeration methods/bioremediation, it could free up land for agricultural use, reduce the impact on climate, and reduce cleanup costs and groundwater contamination. My hypothesis was that the group of paint cans with the turned soil and Pseudomonas fluorescens will have achieved the best remediation. To test this, I used different aeration techniques (turn, holes, none) and planted Pseudomonas fluorescens into half of the paint cans of each aeration technique. I gathered samples at the beginning of experimentation and from each of the groups at the end. The results of my experimentation showed that remediation was best achieved in the paint cans of group F. The total extractable hydrocarbons of the average of this group were, at minimum, 287.6 mg/kg less than the other groups. Based on these findings, I was able to accept my hypothesis. After completing statistical analysis, I found that my data was not statistically significant. To further continue this investigation and to further achieve remediation, I would try different methods of bioremediation, look to perform experimentation during a warmer time of year, and try to better distribute the hydrocarbons in the soil. I would also look to continue remediation efforts for longer periods of time.

Identification and Analysis of Metabolic Inhibitors in *ctnnb1*-driven Hepatocellular Carcinoma (HCC) in Transgenic Zebrafish *(Danio rerio)*

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Mentors: Chad VanSant-Webb, MPH2 and Alexis Ross, University of Utah
Sponsor: Dr. Kimberley Evason, MD, PhD, Huntsman Cancer Institute and Department of Pathology, University of Utah

Liver cancer is the third leading cause of cancer deaths worldwide. In 2020, there were about 830,000 deaths due to liver cancer and over 900,000 new diagnoses. About 90% of all primary liver cancers are characterized as hepatocellular carcinomas (HCC). The incidence of HCC is expected to continue growing due to the ongoing rise in metabolic disorders, obesity, and diabetes.

Mutations in the gene *CTNNB1*, which encodes β-catenin, account for ~20-40% of HCC cases. Dr. Evason previously characterized a line of transgenic zebrafish that expresses hepatocyte-specific activated β-catenin, resulting in constitutively active Wnt signaling and significant liver enlargement, which recapitulates human HCC. Our aim is to identify and analyze compounds which have anti-tumor effects, in order to better understand the mechanisms of HCC.

In this project, we screened 240 metabolic/protease-related compounds and performed confirmation testing on those that showed the most significant reduction in liver size. Quantitatively, we found that exposure to FAAH-IN-2 resulted in the greatest reduction when treated 3-6 days post fertilization. Furthermore, since FAAH-IN-2 is a derivative of gefitinib, a clinically approved chemotherapeutic, we confirmed that the effects seen with FAAH-IN-2 were independent of gefitinib, as exposure to gefitinib did not impact transgenic larval liver size.

Our work successfully identified a key compound that significantly decreases larval liver size in transgenic zebrafish. Further study of FAAH-IN-2 could uncover new insights into the role of FAAH in lipid metabolism and may lead to effective treatments for human *CTNNB1*-mutated HCC and HCC as a whole.

A Behavioral Study of Public Health Messaging: Community, Self-interest, Vulnerability & Racial Bias

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Mentor: Brigham Daniels, University of Utah Law School

Finding the most effective ways to motivate people to take science-backed public health measures is critical. I wanted to see if messages encouraging people to protect *others* are more effective than messages encouraging people to protect *themselves*, and also whether other-oriented messaging is more effective when focused on the whole community or on *particularly vulnerable* people. I also wanted to investigate whether the race of vulnerable people featured in public health messages affects people's actions.

I displayed KN95 masks outside a store and then rotated different messages encouraging people to take an upgraded mask. For each message, I observed how many people walked by the sign and how many took a mask. Based on my observations (N=1460), community messaging was most effective in persuading people to take a mask, more effective than self-protection (χ^2=4.1143, p=.0425) or vulnerability (χ^2=12.5462, p=.0004). Although the vulnerability messaging was other-oriented, it was statistically indistinguishable from the self-protection and control messaging.

For messages featuring a vulnerable person, the data unfortunately confirmed my hypothesis that people would be more likely to take a mask if the sign showed an elderly white person rather than an elderly Black person. Moreover, people were even less likely to take a mask if the sign showed an elderly Asian person. These results were also statistically significant. In a follow-up Qualtrics survey (N=2090), people likewise expressed higher willingness to receive a COVID-19 booster if the featured vulnerable person was white than Asian (p=<.0001).

Mechanical Properties of Starch-based Plastic Food Storage Films Phase II

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Mentor: Mrs. Cheryl Kluesner; Beckman Catholic

An increase of natural polymer-based film materials in the food industry has occurred in recent years to reduce petroleum-based plastic accumulation. Previous research developed starch-based food packaging films incorporating antimicrobial agents. Films were examined for microbial growth on fresh foods, successfully reducing fungal presence. The focus of this research evaluated the tensile strength, elongation/ductility, biodegradability and impact resistance of the films. New films were fabricated and examined in comparison to old films from previous research. Tensile strength was examined using a Vernier Structures and Materials Tester (VSMT). This assessed samples at fracture point with force in newtons. Displacement in centimeters was recorded. The biodegradability of films was tested by placing strips of each film treatment in distilled water and white vinegar, assessing degradation of the films. It was hypothesized that the treated films would have a stronger tensile strength and a higher impact resistance to puncture as compared to petroleum-based cling wrap and the treated starch-based films would be biodegradable based on the content. Hypotheses were supported as the treated starch-based films significantly showed a higher fracture stress and force. Hypotheses related to degradation were supported as films deteriorated in high moisture conditions as compared to petroleum-based films.

Using Lutjanus Campechanus Scales as a Biosorbent to Filter Cu2+, Pb2+, and Cd2+ from Water

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Teacher: Jennifer Reed

In recent years, heavy metals have become an environmental concern across the U.S. Metals found in waterways lead to the need for efficient and cost-effective removal methods from drinking water. Some dangerous heavy metals in water are copper (Cu^{2+}), lead (Pb^{2+}), and cadmium (Cd^{2+}). This project determined if red snapper fish scales could be used to reduce Cu^{2+}, Pb^{2+}, and Cd^{2+} in water samples. In phase one, 0.025 M, 0.05 M, and 0.10 M solutions of each metal were prepared. Solutions were then distributed into flasks, 1g of red snapper scales were added, and the flasks were shaken on ONiLAB Digital Orbital Shaker. The metals were precipitated and massed. In phase two, 0.05 M concentration of each metal was prepared and distributed into flasks. 0.5g, 1.0g, and 2.0g of red snapper scales were added, the flasks were shaken, and the metals were precipitated and massed. The hypotheses were that the 0.025 M and 0.05 M concentrations would present with a reduction in metal mass and treatment with 1.0g and 2.0g of red snapper scales would result in a reduction. It was determined that 0.025 M and 0.05 M concentrations and 1.0g and 2.0g of red snapper scales for all metals had a significant reduction. In phase one, the concentration of 0.10 M $Pb(NO_3)_2$ had a significant reduction. In phase two 0.5g $Cu(NO_3)_2$ had a significant reduction.

Determining Fat Preference for Triple Negative Breast Cancer Cells

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Mentor: Jiaqing Hao

Breast cancer (BC) is the most prevalent cancer in women worldwide. Of the BC subtypes, triple negative BC (ER-, PR-, HER2-) has the worst prognosis due to the lack of effective receptor-targeting treatments. How to manage these patients presents a great challenge in healthcare. Fats are essential nutrients in diets. Dietary Guidelines for Americans recommend following a healthy dietary pattern by replacing saturated fats with unsaturated oils. However, the effect of consuming different unsaturated oils on triple negative BC remains unclear. Herein, we cultured triple negative 4T1 and MDA-MB-231 cancer cells and treated them with common unsaturated fatty acids (FAs), including oleic acid (OA), linoleic acid (LA), eicosapentaenoic acid (EPA) and docosapentaenoic acid (DPA), respectively. The effect of these FAs on cancer cell growth and death was analyzed using different methods. We observed that OA and LA promoted proliferation of 4T1 and MDA-MB-231 cells whereas EPA and DPA induced the death of both types of cells. These data suggest that individual unsaturated FAs exert different effects on triple negative BC. Thus, women with triple negative BC might avoid consumption of oils high in OA/LA (e.g., olive, canola). Instead, oils high in EPA/DPA (e.g., fish oil) are highly recommended.

Turmeric Bandage: A Natural and Sustainable Way for Faster Wound Healing

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Teacher: Ms. Asha Sharma

Turmeric has been applied to a bleeding wound because of its antibacterial property and fast healing quality. But applying dry turmeric is significantly messier and troublesome to carry in a first-aid box than simply putting on or carrying a bandage. However, research shows that even though bandages protect wounds from reinjury, they do not provide a nourishing environment for the wound, nor do they speed up the healing process. Studies have shown that even wounds resulting from a clean surgery can have an infection rate up to 8% among the general population, and a spike of 20% in elderly above 60 years old. If bandages were more effective in preventing bacterial growth on a wound, they could easily avoid potentially lethal infections. This inspired the creation of a turmeric bandage that releases curcumin to enhance the healing process while protecting the wound from bacterial infections. In order for the curcumin to do its job effectively in the bandage, a binding agent was mixed with turmeric. Using this medicinal paste, multiple different materials for the actual bandage were tested. It was determined that an organic cotton cloth and compressible bandage were most effective. The resulting turmeric bandage prototype is biodegradable, compostable, portable, small, and lightweight. It will be one of the most effective solutions to a normal bandage because of its ability to alleviate the healing process.

Pura Aerem: A Five-Stage Extension to Catalytic Converters Designed to Purify Gasses and Pollutants Exiting Gas-Powered Vehicles

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Mentor: Dr. Patrick Zimmerman, 3M

Ambient air pollution contributes to a 7-million annual mortality rate, with gas-powered vehicles among the leading contributors. The current technology being used within gas-powered vehicles is the catalytic converter, converting gasses such as CO, HC, and NO_x into CO_2, H_2O, N_2, and other trace pollutants. The goal of this study was to improve catalytic converters, making the outputs less toxic. Pura Aerem was developed as a five-stage extension to catalytic converters designed to purify exhaust gasses exiting gas-powered vehicles. Pura Aerem uses diffusion-interception capture methods to reduce levels of particulate matter (PM), photoelectrochemical oxidation (PECO) technology to destroy trace gasses and pollutants, such as VOCs and O_3, C_{60} Multi-Walled Buckypaper (MWBP) screening used to encapsulate CO_2 particles, and an electrolysis chamber paired with a hydrogen fuel cell to utilize H_2O for an alternative energy source. This study measured the levels of various gasses and pollutants in given samples over a 5-minute period from four environments. Altogether, Pura Aerem reduces Fine PM (FPM) and Coarse PM (CPM) by 99.275% and 99.587% (respectively), reduces CO_2 by a minimum of 92.844%, reduces CO by nearly 100%, and increases O_2 levels by approximately 744.444%. Chi-square tests were conducted, indicating that there was a significant FPM and CPM reduction correlated to the use of Pura Aerem ($p=2.54\times10^{-11}$, $p=3.31\times10^{-11}$–significance level of 0.05–respectively). Pura Aerem is a promising solution for future applications within internal combustion engines to reduce carbon emissions.

The Effect of Palmitoylation on Drug Uptake Transporters in Human Hepatocytes

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Principal Investigator: Dr. Bruno Hagenbuch, University of Kansas Medical Center

The Organic Anion Transporting Polypeptide (OATP1B1) is a hepatic active transporter involved in the uptake of endogenous compounds and xenobiotic therapeutics. OATP1B1 is localized within lipid rafts in the cell membrane, frequently involved in an attachment process known as S-palmitoylation, a reversible post-translational modification. Post-translational modifications such as S-palmitoylation can affect the phenotype of the protein, at times massively affecting its ability to uptake substrates such as the xenobiotics and therapeutics it is responsible for transporting. Previous research has shown that single amino acid changes can greatly alter the uptake function and surface expression of proteins such as OATP1B1. The mutant C24A has been observed to affect uptake function when the surface function is normalized for both the mutant and the wild type. Uptake function significantly drops with the mutant compared to the wild type. The purpose of this study is to observe the effects of a single amino acid change at position 24 of OATP1B1 from cysteine to an alanine, specifically, if it de-palmitoylates OATP1B1, either partially or fully. By looking at concentrations of OATP1B1 and C24A in sucrose gradient fractions, it was observed that C24A shifts concentration into the higher numbered fractions. When graphed, this indicates that C24A may be partially de-palmitoylated, allowing it to move in the lipid rafts. This project falls into the category of Biomedical Sciences, subcategory of Pharmacology.

The Role of Estrogen Receptor Alpha in Non-Alcoholic Fatty Liver Disease

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Teacher: Dr. Kenneth Lee, Shawnee Mission Center for Academic Achievement
Mentor: Dr. John Thyfault, University of Kansas Medical Center

Non-alcoholic Fatty Liver Disease (NAFLD) is a range of conditions characterized by elevated intrahepatic lipid stores in people who drink little or no alcohol. NAFLD is currently being investigated by medical and health scientists, particularly in physiology labs. It is associated with many other diseases including obesity, insulin resistance, cardiovascular disease, and type II diabetes, among others. Currently, weight loss and exercise are the only known treatments for NAFLD. Critical to this study, females are less likely to develop NAFLD than males until menopause when estrogen signaling is lost. This suggests that estrogen signaling may play a role in protecting female livers against NAFLD. Possible post-menopausal NAFLD treatments could be discovered by investigating the role of estrogen signaling in the development of NAFLD. We hypothesize that Estrogen receptor alpha (ERα) signaling inhibits the development of HFD-induced NAFLD through the regulation of mitochondrial quality in the liver in response to metabolic stress and that the loss of estrogen signaling reduces the influence of exercise-induced mitochondrial adaptations. Elucidating the role of ERα in the liver could lead to the development of treatments for NAFLD in post-menopausal women, who are at higher risk for NAFLD than pre-menopausal women and men. While this study is ongoing, our data demonstrate the effects of HFD-induced metabolic stress in mouse models. HFD stress increases overall body mass and percent fat mass while causing significant changes in mitochondrial protein expression. Additionally, our data suggest that female mice have mitochondrial respiration adaptations in response to HFD stress.

Using Image Analysis to Study the Effects of Carbon:Nitrogen Ratios in Mock Root Exudates on *E. Coli* Chemotaxis

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Teacher: Chelle Gillan, Central City High School
Mentor: Tessa Durham Brooks, Doane University

With an ever-growing global population, discovering how to grow crops more efficiently is imperative. Plant-microbe interactions in soil are essential to plant growth, and nutrients are a key component of these interactions. The purpose of this study was to test the effects of the carbon:nitrogen (C:N) ratios of mock root exudates, or compounds released by plants to attract bacteria, on Escherichia coli chemotaxis using a method currently being developed by researchers at Doane University. Image analysis was used to measure the movement of bacteria towards or away from two mock root exudate solutions at two concentrations. Issues with the methodology were discovered upon data analysis, so no conclusive results were found on the effects of the C:N ratio of exudates on chemotaxis, but progress was made towards optimizing the image analysis method for measuring chemotaxis. There were also trends in the data such as a concentration effect that could be reasonably explained by biological processes and should therefore be tested further. Research on developing this method should continue because it is time and cost efficient and able to show the process of chemotaxis, which is not true of other current methods of measuring chemotaxis.

The Effects of Varied Thickness on the Practical and Theoretical Efficiency of Zinc Oxide Solar Cells

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Teacher: Chelle Gillan, Central City High School
Mentor: Ned Ianno, University of Nebraska Lincoln

The purpose of this experiment was to see how the thickness of ZnO_2 solar cells affected the efficiency of the cells. I chose this topic because I find solar cells fascinating, and I hope to be able to contribute to the field of photovoltaics. It was predicted that up to a certain point, the efficiency of the cells would increase, and after that point the efficiency would decline and plateau. The way I reached this hypothesis was through the PC1D solar cell simulation. The simulation showed that under perfect conditions, at approximately 8.2 um thick, the efficiency would increase by approximately .06 and the base Isc and base Voc would decrease by .007 and .006 respectively. To compare to this, solar cells were produced in a lab. The cells were placed in a sputtering system for 15 minutes, 30 minutes, 45 minutes, and 60 minutes to produce varied thicknesses of zinc-oxide layers. The data showed a difference in the base max power, base Isc and base Voc of thicker cells. A possible explanation for this is a decreased amount of surface recombination than in thinner cells. This would increase the efficiency by decreasing the number of electrons that travel to the bottom of the cell, without contacts, and the energy is lost. To extend this study it would be interesting to vary the sputtering process for longer, and take more trials to allow for statistical analysis to be possible.

Characterization of Engineered Chimeric Protein LLHP Repression Through the Induction of DNA Looping

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Teacher: Dr. Kenneth Lee, Biotechnology Signature Program

DNA looping is a method of gene regulation that plays an important role in controlling transcription. Previous research has shown that DNA looping occurs as a method of gene regulation when transcription factors that are bound to operators interact and tetramerize, causing the DNA to form a loop. Another area that has been explored is how intersite spacing affects DNA’s ability to loop. As the operator spacing changes, the helical shape of DNA affects the proteins bound onto the operator's ability to interact and form a loop. Although it is known that the transcription factor's ability to tetramerize correlates to DNA looping, it has not been explored how

the addition of a tetramerization domain to another protein could cause DNA looping. It is my hypothesis that by adding a tetramerization domain to a protein construct that does not induce DNA looping usually, will be necessary and sufficient to induce looping in said protein. I will explore this using repeat ONPG assays to test the level of repression which should increase and decrease depending on whether LLhP is inducing looping in DNA. By exploring how protein domains work independently of each other, it allows for a greater understanding of how to engineer proteins for the desired function.

KENTUCKY

Novel Organ Preservation Approaches Enhance Hepatocyte Survival for Liver Transplantation

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Mentor: Dr. Kumaravel Velayutham

Liver transplantation is the most effective therapy for patients with end-stage liver disease. The process of liver transplantation involves the removal of the liver from a brain-dead donor body, storing this organ for transportation, and allowing it to be transplanted into another body, all while preserving the liver without significant damage. Preservation solutions and techniques are crucial for liver organ quality, directly relating to morbidity and survival after transplantation. Currently, static cold storage (SCS) is the standard method for organ preservation. This involves creating hypothermic (cold) conditions by reducing the organ temperature from 37° to 0°C helping to reduce metabolic demands of the cells by 12-fold and helping preservation. There are many complex physiologic interactions that occur during the process. However, preservation time with SCS is limited as prolonged cold storage increases the risk of early graft dysfunction that contributes to chronic complications. In this study, I developed [1] a newer organ preservation solution followed by transporting the liver in [2] perfluorocarbon (PFC) containing a "two-layer method" to supply oxygen in the solution. I also evaluated [3] oxygen persufflation (OP) and proved that it improved the survival of rat hepatocytes. Wister rat (n=24) livers were procured and subjected to three different experimental protocols. PFC significantly improved hepatocyte viability and adenosine triphosphate levels in comparison with UW cold storage. Albumin production or urea synthesis was significantly higher after oxygen persufflation. I developed a novel organ preservation approach to improve the survival of hepatocytes for liver transplantation.

A Form-Correcting Device for Weightlifting

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Teacher: Keri Polevchak, duPont Manual High School

Maintaining proper form during weightlifting is important for progressing with training. Lifting heavier weights with incorrect form can reduce training efficacy, exercise the wrong muscles, or even cause injury. However, not everybody has access to a personal trainer who can ensure proper weightlifting form. To address this need, the engineering goal was to build a wearable apparatus that guides beginner weightlifters by helping them maintain proper form while performing deadlifts. The apparatus consisted of a wearable device and a mobile app that worked in conjunction to meet the goal. The device analyzed the wearer's form using inertial measurement units, utilized an algorithm to determine what type of feedback the user needed, and sent this information to an app. There, this feedback was displayed, along with visuals of the user's posture, so they would get a better understanding of their form. Additionally, the device was constructed in layers to be comfortable to wear. To determine whether the engineering goal was met, participants were asked to evaluate several characteristics. The device comfort level and app user-friendliness were rated highly by the participants, indicating that the design interface was satisfactory. The device effectiveness and app usefulness were also satisfactory, but improvements could be made to the accuracy of the feedback algorithm. Overall, the engineering goal was met, and possibilities for future development include adapting the design for a variety of exercises.

Synthesis of *4d*- and *5d*-Element Based Transition Metal Oxides

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Mentor: Dr. Jasminka Terzic, Western Kentucky University

Transition metal oxides (TMOs) have long been the topic of research due to their wide range of potential technological applications (e.g., high-density magnetic data storage and spintronics). *4d*- and *5d*-element based TMOs in particular exhibit properties that have not been observed in *3d*-TMOs, as a result of the presence of strong spin-orbit interaction (SOI), as well as competition of SOI with comparable energy scales, like the Coulomb interaction. This research focused primarily on the synthesis of TMOs containing the elements molybdenum, ruthenium, niobium, and tungsten. Both polycrystalline and single crystal synthesis were performed. Characterization techniques such as powder x-ray diffraction (powder XRD) and energy dispersive x-ray spectroscopy (EDS) were done on the crystals to determine the resulting phase(s) of each attempted crystal growth. Although many crystals were synthesized, EDS data demonstrated that the atomic ratio of strontium to ruthenium in my single crystal samples was 1:1. This indicates that the single crystal growth of $Sr_2Ru_2O_7$ was possibly successful. More data must be collected through single crystal x-ray diffraction (sXRD) for complete verification. Future measurements of the magnetization, heat capacity, and resistivity of the single crystal samples may reveal that the crystals have properties which give them the potential to advance modern technology.

Vital Signs Based User Authentication Using mmWave Radar

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Teacher: Keri Polevchak, DuPont Manual High School

The goal of this project is to use a single radar for contactless, continuous and unobtrusive biometric authentication (BA), which involves determining the identity of a user by comparing the user's radio sensed data with existing biometric templates to determine their resemblance. The project includes radio data collection, random signal processing, data analysis and algorithm development. Specifically, the Radar is placed at a fixed location, pointing to the user to be authenticated. It sends out a low-power high frequency electromagnetic wave that is reflected by objects in its path. The hypothesis is that the reflected signal contains a user's unique biometric information that can be extracted and matched to its biometric signature. In order to clean the signal that also picks up random body movements and environmental noise, the raw signal is processed by a number of procedures including empirical mode decomposition and digital signal filtering. Once the cleaned signal containing consecutive cardiac cycles is obtained, unique features of the cardiac motions are extracted to train a machine learning based algorithm for user classification, where each user belongs to a unique class. For a database consisting of a dozen users, experimental results show that the machine learning based algorithm is able to detect a user's unique cardiac movement pattern, and the authentication accuracy is over 98%.

Decentralized, Autonomous Drone Swarms for Real-Time Mapping Applications and Natural Disaster Relief

Richard Lian
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Decentralized, autonomous drone swarms have great potential in mapping of an unexplored environment, search and rescue, and intelligence, surveillance, and reconnaissance (ISR) applications. Drone swarms can complete missions that are too dangerous or complex for humans and single drones to perform. Most recent works on autonomous drone swarms focus on centralized swarm coordination and navigation planning, while research on decentralized drone swarms is still a large gap due to the complexity of a multi-robot system and higher costs. Moreover, recent drone mapping applications widely use photogrammetry with an RGB camera due to its low-cost, lightweight, and color information, which fails in outdoor settings with inadequate illumination. Furthermore, photogrammetry methods have low topographical accuracy and depth measurement precision, which results in unreliable digital terrain models. In our research, we propose a distributed system focused on coordinating the actions of an entire fleet by continuously updating the status of individual drones to neighboring drones. Additionally, low-cost LiDAR sensors are used to generate robust digital terrain models from point cloud data due to higher accuracy and volume of data due to a high sampling rate. LiDAR is able to generate real-time maps with high resolution with fewer computational resources and time needed compared to photogrammetry. Furthermore, the compact size of point cloud data reduces the bandwidth required for sharing data across the drone swarm. The results demonstrate the feasibility of a low-cost decentralized drone swarm architecture with highly efficient and accurate real-time 3D mapping capabilities, enabling faster formation of real-time maps.

LOUISIANA

Combustion Carbon Capture Via Aqueous Solutions

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The purpose of this experiment was to determine if carbon dioxide (CO_2) from combustion emissions could be effectively removed using post combustion water absorption. Combustions sources across industry (e.g. boilers and furnaces) represent a significant contributor of the carbon dioxide to greenhouse gases. If absorbing the CO_2 by conventional means at the point of generation is successful, then a potential cost-effective solution of preventing the CO_2 from reaching the atmosphere is possible. The research hypothesis states that carbon dioxide emissions are reduced by using post combustion water absorption. To conduct this experiment, a small-scale combustion apparatus was designed and fabricated. Trials were then conducted using the apparatus to test various water baths of tap water, distilled water, and LSU Lakes algae water. CO_2 concentrations at key points within the apparatus were measured every 15 seconds for multiple 10-minute trails. The data set was analyzed based on the CO_2 difference before and after the water bath. From this experiment, one can statistically conclude that the solutions with combustion were able to remove more CO_2 than the solutions without combustion. Overall combustion CO_2 removal rates were approximately 14%. The LSU Lake algae water was shown to remove the most CO_2 at ~16%. In conclusion, the statistically significant experimental data results in rejecting the null hypothesis.

Intraoperative Histological Analysis of Squamous Cell Carcinoma Tumor Margins using a Convolutional Neural Network

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Squamous Cell Carcinoma (SCC) is the second most common nonmelanoma skin cancer. If left untreated, SCC can be aggressive, with potential to deform adjacent tissue or metastasize. Most cases of SCC are treated using Mohs Micrographic Surgery (MMS), a surgical method for the excision of cancerous tissue and the rim of the surrounding normal tissue. During MMS, intraoperative histological analysis of tumor margins is performed to ensure complete tumor removal. However, this process is demanding due to the examination of multiple margins in contingent timeframes and challenges with frozen section specimen quality. Automated approaches to performing intraoperative margin assessment should be considered. This project presents a convolutional neural network (CNN) for the automated analysis of histology images of squamous cell carcinoma tumor margins. A dataset of 95 WSIs was collected from patients undergoing SCC tumor excision in the MMS setting. A model was constructed and trained with these datasets. Upon evaluation, this model demonstrates the ability to accurately and rapidly analyze histology images of tumor margins of SCC, with an AUC-ROC score of 0.923 and an average prediction time of 33 seconds per WSI. Integration of this algorithm in workflows could significantly assist pathological analysis of tumor margins during the surgical procedure.

The CaSR—GSH Interaction: Finding an Effective Antagonist

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As the second leading cause of death, cancer has negatively impacted the lives of millions across the globe both directly and indirectly. In this study, we aim to stunt the rapid proliferation of cancer cells by targeting the interaction between the Calcium-Sensitive Receptor (CaSR) and Glutathione (GSH). Cancerous cells tend to release large amounts of GSH, an antioxidant, to counteract high metabolic activity, and this GSH activates CaSR, leading to an increase in proliferation of endothelial cells and, therefore, angiogenesis and vascularization of cancerous tissue. We hypothesize that quinazolinone derivatives, which recent publications have shown to have high inhibitory potential against CaSR, can bind to CaSR and outcompete endogenous agonists, thereby, abrogating GSH-mediated CaSR activation and stunting cancer cell proliferation. Computational drug repurposing methodology was used to create a compound library of quinazolinone-containing drugs, which were screened for binding potential to CaSR using AutoDock Vina. The highest ranked drug based on binding affinity, intermolecular interactions, and pharmacological analysis was chosen for in vitro validation. Luciferase assays and BRET Assays were performed on a stably transfected line of HEK-293 cells to determine efficacy of the drug in inhibiting CaSR activation. In this study, we highlight the potential of Idelalisib as an inhibitor of CaSR—GSH mediated downstream signaling responses such as endothelial cell proliferation in silico and in vitro and provide further evidence for the pre-clinical development of quinazolinone-containing compounds as CaSR inhibitors.

Removing Lead(II) and Chromium(VI) Ions From Water Using UV-C Light and An Immobilized TiO2 Photocatalyst

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The United Nations deems clean water a human right. Even so, the World Health Organization reports that over 2 billion people worldwide still do not have access to clean running water. Low-income and minority groups are most impacted by water insecurity and pollution.

Lead(II) and chromium(VI) are two of the most common water contaminants. When ingested at even minuscule concentrations, these contaminants can cause various health problems, including cardiovascular disease, brain and nervous system damage, and cancer.

In this project, the removal of lead(II) and chromium(VI) was tested using a photosystem consisting of a TiO2 photocatalyst immobilized onto a quartz veil (QV) and UV-C light. Concentrations of lead(II) and chromium(VI) levels were taken with inductively coupled plasma atomic emission spectroscopy (ICP-OES). The data collected showed that the proposed photosystem can remove significant levels of lead(II) and chromium(VI) in a way that is both environmentally sustainable and cost-effective. These results indicate that this photosystem can potentially solve water insecurity and improve the livelihoods of millions of people currently suffering from the water crisis.

Novel Imaging Approaches for the Quantification of Changes in Perivascular Space Volume and Morphology in Response to Transcranial Direct Current Stimulation

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Purpose: Though behavioral effects of transcranial direct current stimulation (tDCS) are well-documented, a gap exists in current literature on its effects on glymphatic system dynamics and perivascular space (PVS) structural features. This is an issue of particular importance due to the relationship between PVS enlargement and impairments in waste clearance.

Methods: Structural MRI data was gathered for 5 neurologically healthy patients before and within one hour after receiving anodal tDCS (lasting 20 minutes) in the primary motor cortex at Brigham and Women's Hospital. Structural MRI data for 30 control group patients were also gathered from the Human Connectome Project. For each subject and session pairing, the T1w and T2w images were coregistered, upsampled, masked, corrected, and segmented. The PVS visibility enhancement procedure described in Sepehrband et al., (2019) was utilized. PVS masks for white matter (WM) and basal ganglia (BG) were generated and analyzed using the Quantitative Imaging Toolkit and ImageJ. Analyses made using unpaired t-tests.

Results: BG PVS volumes demonstrated significantly greater increases between before and after scans in the tDCS group compared to the control group ($p=0.0078$). ImageJ analysis of BG PVS cross-sectional areas demonstrated significant PVS dilation in response to tDCS ($p=0.0033$). Analysis of various individual BG suggests the significant changes were isolated to the right nucleus accumbens and left putamen (both $p<0.05$).

MARYLAND

Optimal Design of Arbitrary Waveguide Bends for Footprint-Efficient and Low-Loss Silicon Photonic Resonators

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Mentors: Dr. Gregory Moille, Joint Quantum Institute, NIST/University of Maryland, College Park, MD and Dr. Kartik Srinivasan, Microsystems and Nanotechnology Division, National Institute of Standards and Technology, Gaithersburg, MD

Integration of photonics components onto chips has revolutionized modern data communications and sensing, as it allows for the mass fabrication of devices which can transmit and guide light at the scale of the wavelength of light itself. Circular ring resonators, in particular, are used to transform continuous input light into pulse trains which find applications in accurate time keeping, distance ranging, sensing, and metrology. Since the pulse train is driven by the distance traveled by light in each roundtrip, the gigahertz bandwidths needed for these technologies require rings with relatively large millimeter-scale circumferences, defeating the purpose of compactness associated with integration. The implementation of 'racetrack' resonators has long been proposed as a way to achieve a large circumference with minimal footprint, however their dispersion—which must be controlled for stable pulse generation—is more difficult to engineer because they lack the radial symmetry of rings, making straightforward design a challenge. In this paper, I address this challenge by presenting a differential application of transformation optics from bulk propagation modified for nanophotonics. This mathematical transformation will be used to unravel periodic resonators such as racetracks into straight-waveguide tapering optimization problems which are simple to dispersion engineer. This tool will open the door for intuitive design and simulation of previously inaccessible resonator structures by mapping rotationally asymmetric resonators into equivalent straight waveguides with translational symmetry. This unprecedented control over light-matter interaction in resonators will allow for the design of footprint-efficient racetracks for quantum frequency conversion, synthetic frequency dimensions, and frequency comb generation.

Investigating Lyssavirus CNS Infection and Control with a Monoclonal Antibody *in vivo*

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Infections with rabies virus (RABV) and related lyssaviruses are uniformly fatal once virus accesses the central nervous system (CNS). Current immunotherapies are thus focused on the early, pre-symptomatic stage of disease, with the goal of peripheral neutralization of virus to prevent CNS infection. Previous lab research found that a single dose of F11 monoclonal antibody limits Australian Bat Lyssavirus (ABLV) load in the brain and reverses any signs of progression for the disease following lyssavirus infection, even when administered after virus replication in the CNS. However, the mechanism by which F11 controls ABLV infection is not known. Here, I investigated if F11 is capable of entering the CNS during infection and identifying brain resident cells that are infected by ABLV. For testing purposes, either the mice were infected or uninfected, and they were either untreated, treated with F11 three days after infection, or treated with F11 five days after infection. Via fluorescence-based antibody stain analysis, I found that F11 is capable of entering the CNS suggesting that the blood brain barrier is impaired during ABLV infection. Using histology and antibody staining I also found that astrocytes and neurons within the hindbrain and cerebellum were infected with ABLV. These discoveries suggest that immunotherapy may be efficacious in human patients even after ABLV, a lethal neurotropic virus, has entered the CNS.

PreVis: Real-time Motion Forecasting Using LiDAR Technology

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LiDAR is shaping the future as we know it. From its uses in a wide variety of industries such as topographical surveying, medical applications, transportation aids, and law enforcement, it offers accurate and consistent results. To analyze 3D and 2D environments, however, current solutions have either been power-consuming or very expensive. The proposed solution to this problem, called PreVis, uses a single LiDAR to scan its environment. The output is combined with a novel 2-step spatial localization and motion-forecasting algorithm that allows for the motion of an object to be tracked and predicted, effectively "filling in" for any missing information. The localization algorithm has been pruned with over 40,000 computer-simulated tests, showing nearly 100% success in finding objects. The Motion-Forecasting algorithm is split into Kalman filtering for error suppression and cartesian/parametric polynomial fitting for path recognition of a moving object. Polynomials with up to 30 degrees are tested for multicollinearity and overfitting using MSE and limiting degrees of freedom. In the end, the localization algorithm was able to collect on average 48 data points in a 10-second window for a moving person. These data points were fed into the motion-forecasting algorithm. The best algorithm was the 2-degree parametric polynomial fitting with a mean squared error of 17 but limited overfitting. This concept can be used as a guide for those with disabilities, enhanced collision avoidance systems in automobiles, and much more. PreVis opens the door to inexpensive and highly accurate motion prediction using LiDARs.

MICHIGAN

WriVision: A Machine Learning Model for Quality Control of Wrist X-Rays

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Radiologists are heavily reliant on X-rays for precise medical diagnosis. However, the acquisition of suboptimal views during X-ray imaging can lead to misdiagnosis, potentially putting patient care at risk. To address this issue, we designed and trained an advanced artificial intelligence model that can provide quality control for technologists during X-ray acquisition.

Our approach involved creating a Convolutional Neural Network based on the DenseNet121 architecture that could identify the true projection, laterality, and presence of cast or hardware on our dataset of 6823 de-identified patient radiographs. Our model was trained in batches of 64 images with 30 epochs, utilizing a learning rate of $1x10^{-3}$, a decay of 0.3 with a minimum threshold of $1x10^{-6}$ and a dropout of 0.1 to prevent overfitting.

To test our model, we utilized a 5-fold stratification validation, allowing us to evaluate the model's efficacy on every image in our dataset. Our results demonstrated an impressive F1 score of 93.1 for projection, 78.7 for laterality, 96.83 for the presence of cast, and 92.12 for the presence of hardware.

Our team is currently working on developing a software that integrates our model into existing X-ray software solutions such as dicomPACS. This software will provide technologists with real-time predictions for the four classes, alerting them if any issues arise and allowing for prompt corrective action, including rescanning the patient. By ensuring optimal views during X-ray acquisition, our innovative model has the potential to greatly enhance patient care.

3D Acoustic Simulation and Optimization Algorithms for Transcranial Focused Ultrasound Delivered with Stereotactic Robotics

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Neurodegenerative diseases, such as Alzheimer's disease, are one of the leading causes of disability and death worldwide. Current pharmaceutical treatments for these diseases are hindered by the lack of efficient drug delivery methods across the blood-brain barrier (BBB). Fortunately, focused ultrasound (FUS), a rapidly emerging, noninvasive clinical device, can open the BBB to increase the bioavailability of therapeutics in the brain for improved medical treatment. Although beneficial in various clinical settings, FUS suffers from attenuation and distortion caused by the heterogeneous human skull, which yields a deviation between the focal point of FUS and the target. Finding an optimal placement of the transducer with respect to each subject and desired target is very challenging. In this paper, I define this problem as constrained optimization and develop a novel iterative search algorithm to optimize single-element FUS transducer placement based on accurate 3D acoustic simulations of transcranial FUS propagation. From digital medical images, I present an automatic, universal framework to reconstruct high-fidelity acoustic and geometric properties for precise representations of skull heterogeneity and accurate 3D FUS simulations. Then, I design and implement a novel, graphics processing unit-accelerated iterative search algorithm to optimize FUS transducer placement. My algorithm outperforms the state-of-the-art, achieving a high accuracy and minimal error of 3.85 ± 1.37 mm and 3.56 ± 2.12 degrees. The novel modeling, simulation, and search algorithm are integrated into a surgical robot to establish an end-to-end framework for patient-specific FUS treatment, such as BBB opening for drug delivery and thermal ablation of cancerous tumors.

Analyzing the Gut Microbiome through Stool Studies of Patients with COVID-19

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With the beginning of the COVID-19 pandemic, a vital deliberation emerged regarding the disease's effect on patients' gut microbiomes. The gut microbiome comprises the microorganisms that reside in an animal's digestive tract and are crucial for biological homeostasis. This study assessed the possible consequences COVID-19 may have on patients' gut milieu based on fecal samples.

The study's methods were approved by Wayne State University's Institutional Review Board. This was a prospective study in which patients' stool samples were periodically collected. Data collection included patients' general backgrounds, prior comorbidities, hospitalization information, and the presence of multi-drug resistant organisms (MDRO), C. difficile, or COVID-19. Additionally, information was recorded on the number of amplicon sequence variants (ASVs) detected in each patient's stool samples, as a measure of gut diversity. When comparing the gut microbiomes of the COVID-19 positive cohort, C. difficile positive cohort, MDRO positive cohort, and healthy cohort, the COVID-19 cohort (128.5 ASVs) had slightly less diversity than the healthy cohort (136 ASVs), but still greater diversity than the C. difficile (84.4 ASVs) and MDRO cohort (92.3).

The research reflects that the variance in gut microbial diversity between the different cohorts may be because of the presence or absence of antibiotic usage and resistance. This strengthens the hypothesis that lack of exposure to gut bacteria due to increasing antibiotic usage can lead to infectious diseases. Additionally, gut microbiome differences may explain the presence of post-acute sequelae of COVID-19 ("long COVID") in some patients.

The Severity of Blood Brain Barrier Dysfunction in Penetrating Compared to Concussive Traumatic Brain Injury

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Penetrating and concussive traumatic brain injuries (TBI) remain major health concerns and are associated with a variety of clinical implications such as memory loss and cognitive deterioration. In particular, recent studies have highlighted the correlation concerning both forms of TBI and cerebral edema due to blood-brain barrier (BBB) dysfunction. More specifically, TBI can cause alterations in expression of proteins critical for maintaining BBB function and disruption in BBB permeability. This study aims to analyze the cascade of events affecting the BBB post-TBI and how type of injury, namely penetrating versus concussive, can affect these events. Analysis of current studies suggests that alterations in BBB permeability and decreased tight junction protein expression are more drastic in penetrating TBI than in concussive injuries. The primary focus is on components of BBB damage such as astrocyte damage, decreased pericyte concentrations, and decreased expression of tight and gap junction proteins. Tight junctions are of particular significance since they regulate selective solute transport across the BBB[19]. To assess damage to tight junctions (TJ), changes in occludin expression will be assessed— a component of tight junctions that has been shown to be altered by TBI. S100B and immunoglobulin G are used as measures of BBB permeability as they normally cannot pass through intact BBB. This study incorporates data from both mouse models (CCI versus closed head injury) that closely recapitulate human TBI as well as human studies. Papers have been selected to ensure consistency across timepoints, injury mechanism, experimental measures, and demographics.

MNRR1 Inhibition, a Potential Therapeutic Avenue for Breast Cancer

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Breast cancer affects hundreds of thousands of people each year. Cancer, defined as uncontrolled growth of cells, may occur due to changes in a cell which prevent normal cellular processes that regulate proliferation or cellular death (apoptosis). In breast cancer cells the protein Mitochondria Nuclear Retrograde Regulator 1 (MNRR1) is highly expressed compared to healthy cells. MNRR1, as the name suggests is a biorganellar protein that controls cellular function by acting in two compartments. In the mitochondria, it enhances energy production and inhibits apoptosis, whereas in the nucleus, it controls the transcription of genes involved in stress-responsive pathways. Since MNRR1 controls two key features of cancers- energy production which may affect cellular growth; and apoptosis, we hypothesized that increases of MNRR1 seen in breast cancer lines may play a role in carcinogenesis. Previous work in our lab identified a compound that inhibits MNRR1. We tested if this compound by itself, or in combination with a bonafide anti-cancer drug (Daunorubicin) can prevent breast cancer cell growth and increase apoptosis. Our results indicate that MNRR1 inhibitor decreases cell number and increases cell death when used in combination with Daunorubicin. The current dose of Daunorubicin used in breast cancer treatment is highly toxic to healthy cells as well. These results suggest that MNRR1 is a potential drug target and its inhibition may improve the treatment paradigms by reducing the dose and therefore toxicity of drugs that are currently used in the treatment of breast cancer.

MISSOURI

Sleep It Off: Reversing Alzheimer's Associated Cognitive Deficits Using Memantine Induced Sleep

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Previous studies recognized the role of GABA-A agonist 4,5,6,7-tetrahydro isoxazole-[5,4-c]pyridine-3-ol (THIP) in restoring both short-term and long-term cognitive function in a *Drosophila* model of Alzheimer's disease (APP:BACE flies). Memantine is a mainstream Alzheimer's disease medication that has been shown to slow disease progression, though without restoration of short-term cognitive function. As Drosophila represents an animal model that accurately reflects many aspects of Alzheimer's disease, I hypothesized that memantine would not demonstrate the reversal of short-term cognitive deficits in transgenic APP:BACE flies to the extent to which THIP did in past studies. To test this hypothesis, flies were separated into Vehicle and RU food which maintained them as controls or induced expression of APP:BACE and in turn, Alzheimer's disease-like symptoms. After gene induction, flies were further split into treatment groups and short-term memory was tested in the Aversive Phototaxic Suppression assay, which trains flies to go against their innate phototaxic nature. The results which were limited by small sample sizes and high attrition rates showed no statistical significance of memantine treatment, therefore, failing to reject the null hypothesis.

CONSTITUTIONALITY BOT: Predicting and Justifying the Constitutionality of Legal Cases by Utilizing Natural Language Processing and Reasoning Informed Transformers

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86% of civil legal problems reported by low-income Americans received inadequate or no legal help according to the Legal Services Corporation's 2017 Justice Gap report.
Artificial Intelligence (AI) can be a potential solution to close the Justice Gap and provide equitable legal services to all. Natural Language Processing (NLP) refers to the branch of AI with the ability to understand text, combine computational linguistics and machine learning to produce human-like answers. NLP has been experimented for predicting court judgments, but there are no models looking specifically at predicting whether a legal case is constitutional or unconstitutional. This model not only predicts if an amendment or article of the Constitution was violated but can also provide an explanation for the reasoning behind its prediction. Utilizing an encoder-decoder transformer model called T5, 3,332 cases of the Supreme Court of the United States were collected, formatted, and given as examples to train the model to answer prompts such as "Is the second amendment violated by X?" Although judgment accuracy was not high at 52%, the similarity between supreme court judgments and generated judgments through BERTScore was high (0.7). Amongst the amendments and articles of the constitution, the model seems to be least accurate in predicting cases involving the first amendment.
The Constitutionality Bot is operational and is hosted on Hugging Face website for users to use. This model facilitates the first step towards using NLP to provide legal resources to all, and to reduce barriers to justice in our communities.

Innovative Biocomputational Approach to Decode the Secrets of the 2022 Monkeypox Resurgence

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In mid-2022, a new outbreak of Mpox circulated the world—this time with high infectiousness and transmissibility. In just six months, 30,000 cases were reported. As we recovered from COVID-19, fear of another pandemic heightened. **Two fundamental questions emerged:** What caused Mpox to increase its infectivity, and what structural changes might have contributed?; Will changes in the protein structure affect efficacy of drugs? Experimental studies can take years to answer these questions. By using biocomputational science, we get answers within weeks. A significant bottleneck was lack of basic three-dimensional protein structures for the Mpox replication complex, which makes copies of DNA. My investigation consisted of three objectives: (i) predicting structure of Mpox replication complex, (ii) identifying mutations in the virus that appeared in the outbreak, and (iii) identifying causative factors for increased transmissibility and effectiveness. I used a "lego-brick" approach to protein structure elucidation and developed advanced biocomputational tools for identifying mutational patterns. Among the five components of the minimal replication complex, ten mutations were observed. Two mutations, L108F and W411L, in DNA polymerase play a critical role. Notably, L108F in DNA polymerase protein (apparent only in current outbreak) increases binding affinity between protein and DNA. Both mutations could be crucial to the virus's infectivity. Further, I identified mutational regions in the Mpox virus that could confer resistance. Despite focusing on Mpox, the method and biocomputational model presented can be applied across many areas. Causative factors can be predicted using these methods for any such virus and, thus, future pandemics.

The Effect of Oryzalin on the Polyploidy of *Lonicera maackii* (Amur honeysuckle) as an Invasive Species Management Strategy

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Teacher: Peggy Veatch

Lonicera maackii (Amur honeysuckle) is invasive to Missouri's ecosystems. It has minimal natural predators, crowds out native wildlife, and provides little nutrition to organisms that eat its abundant berries. Current eradication methods are ineffective at reducing *L. maackii's* large biomass. The purpose of this project is to complete the first step of an innovative management strategy. The strategy starts with inducing tetraploidy– a characteristic of having four sets of chromosomes– into sprouts. Once they reach adulthood, the tetraploid plants can be transplanted into ecosystems that are overtaken by diploid– genetically normal– *L. maackii*. When the tetraploid and diploid *L. maackii* cross-pollinate, their offspring will have an odd number of chromosomes and, therefore, be sterile. To induce tetraploidy, *L. maackii* roots were soaked in low concentrations of oryzalin, which is a common herbicide at higher concentrations. Root tips were smashed and stained, allowing their chromosomes to be counted under a microscope. The test group soaked in 120 μM oryzalin consistently induced tetraploidy, with a significant p-value of 0.0058. With a successful first step, the management plan can be further studied to be implemented in Missouri's ecosystems.

Human-Smartphone Interaction using MediaPipe Hands and Active Machine Learning

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Due to the limitations of many human-computer interaction technologies, alternative methods of interaction are developing rapidly, such as voice recognition. Although voice recognition technology has been integrated into smartphones and other devices, it has yet to hold regular use by the majority because of its flaws. Other interaction alternatives, such as gesture recognition, also have advantages over physical hardware, but have yet to be largely implemented into consumer-use. Most gesture recognition systems require extra sensors, cameras, or powerful computer processing not provided by a smartphone. Further, many are limited by the gestures themselves, being restricted to a small set of preset gestures or unable to handle motion, which many gesture-based interactions such as sign language require. This research proposes multiple methods for a smartphone interface system with the use of MediaPipe Hands, a hand segmentation and point extraction data pipeline, combined with custom-built artificial intelligence and machine learning algorithms, to provide a viable and customizable dynamic gesture recognition interface that has the capability to run efficiently on a smartphone, both of which performed at over 90% accuracy.

NEW ENGLAND NORTHERN

Nanovesicles in Broccoli Sprouts as a Naturally Potential Medicine for the Targeted Treatment of Inflammatory Bowel Disease

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Mentor: Professor Tianzhi Yang, Husson University

Inflammatory bowel disease (IBD) is an incurable small intestine and colon disorder. While exerting anti-inflammatory effects, bioactives in broccoli sprouts cannot treat IBD well probably due to their instability in the GI tract and/or inadequate transit into colon cells. The study aimed to investigate if broccoli sprout-derived exosome (BSDExo) nanovesicles can protect bioactives from the upper GI extreme environments and confer selectively targeted delivery of bioactives to inflamed colon cells in IBD. Nanosized BSDExo with 40.1±17.2 nm encapsulated and protected bioactive sulforaphane for 2 hours in stomach-mimicking acid and 24 hours in intestine-mimicking conditions. 25 ng/mL BSDExo quantified by total proteins promoted the proliferation of normal colon epithelial CCD841 CoN cells with a cell viability of 154±5% ($p<0.05$). Both CCD841 CoN and Caco-2 cellular uptake of fluorescence-labeled BSDExo significantly increased with more severe inflammation stimulations. Interleukin 8 (IL-8) secretion from inflammation-stimulated normal colon cells was significantly reduced by the BSDExo treatment ($p<0.05$). BSDExo also significantly recovered the decreased transepithelial electrical resistance (TEER) values caused by inflammations in Caco-2 cells ($p<0.05$). Overall, the isolated BSDExo improved the stability, inflammation-targeting, and therapeutic efficacy of bioactives in colon epithelial cells via a naturally formed nanostructure. Demonstrating that BSDExo interacts with the targeting gut inflammatory cells and regulates anti-inflammatory responses would be a significant step forward in treating IBD.

Polystyrene Microplastics Exacerbate Neuroinflammation in Obese Condition

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Plastics are inexpensive, lightweight, and corrosion-resistant, but microplastics (MPs) that break down from plastics pollute the environment and pose risks to humans. Obesity has nearly tripled despite no significant change in caloric intake over the last few decades, raising concerns about the link of obesity with exposure to MPs. In this study, we performed *in silico*, *in vitro*, and *in vivo* studies to study whether MPs aggravate neuroinflammation in obese conditions. First, to investigate which types of MPs polymers can bind to immune cells, we simulated the molecular docking between three types of plastic polymers (ethylene, propylene, and styrene) and immune cells (macrophage, CD4, CD8 lymphocyte). Docking simulation showed styrene has the highest binding affinity to macrophage. Second, to examine whether MPs could bind to microglia cells, various concentrations of 1 μm green, fluorescent-labeled polystyrene (PS)-MPs were incubated with BV2 microglia cells. Most MPs were captured and phagocytized by microglia cells. Next, to investigate whether PS-MPs can exacerbate neuroinflammation, PS-MPs were orally administrated to high-fat diet-induced obese mice. PS-MPs were found to co-localize with immune cells in whole brain. PS-MPs worsened insulin resistance and fat accumulation in adipose tissue and liver compared to HFD alone mice. PS-MPs also significantly increased CD11c+ inflammatory macrophages in visceral fat and activated microglia in their brain hypothalamus. These results suggest that PS-MPs may significantly exacerbate obese conditions and neuroinflammation by activating peripheral and central inflammatory immune cells.

An Antimicrobial Bacterial Cellulose-Manuka Honey Wound Dressing that Actively Monitors Infections

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Mentor: Mr. Cary James, Maine Math and Science Alliance

Chronic wounds are a significant healthcare threat worldwide, affecting an estimated 6.5 million people in the U.S. and costing the healthcare system an estimated $25 billion annually (10). With the drastic increase in obesity and diabetes, there is a critical need for innovative wound care strategies that accelerate healing and recovery and limit the use of antibiotics through wound monitoring technology. The goal of this study was to develop a biodegradable, antimicrobial wound dressing, for the purpose of detecting infection and healing wounds. Bacterial cellulose (BC), a biopolymer derived from kombucha tea, was purified and loaded with manuka honey (MH) to obtain long lasting antimicrobial properties. Alkaline pH within a wound bed is a strong indicator of infection or biofilm formation. A pH sensing indicator was fabricated by loading anthocyanin, a natural dye extracted from red cabbage (Brassica oleracea), into bacterial cellulose patches, which were incorporated into the MH/BC dressing for the purpose of detecting infections. BC's complex 3-D structure allows MH to slowly release, giving it a more prolonged effect at the wound site. T-test of disk diffusion results indicated MH/BC dressings functioned significantly better than 100% unloaded manuka honey at inhibiting both Gram-positive and Gram-negative *Staphylococcus epidermidis* and *Escherichia coli*, respectively at 48, 72 and 96 hours (*S. epidermidis* P= 0.0164, *E. coli* P= 0.200). This promising multi-functionalized dressing combines the proven antimicrobial benefits of manuka honey with the ability for patients and physicians to quickly identify wound infection.

Creating a Low Cost Non-Invasive Blood Glucose Monitoring System with an Artificial Neural Network and Microcontroller

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Teacher: Dr. Barbara Stewart, Bangor High School

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 main way to treat diabetes 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 typically reserved for richer countries and individuals. The research goal of this study was to develop a low-cost, non- invasive, and accurate glucometer. A ESP32-CAM microcontroller and laser diode 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. The system presented could provide access to essential healthcare to millions worldwide at a low cost and with a non-invasive method. The general methodology could also be expanded to creating wearable biomonitoring technology for healthcare and other fields such as the military.

Game-Based Redistricting for Small-Population States

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Congressional districts are often perceived as being biased towards specific parties or groups. Recently, due to major court cases the problem of gerrymandering has received much attention from mathematicians and computer scientists. One proposal suggests a game-based districting method where two players alternate creating districts, but it does not work for small-population states. This project proposes and evaluates an alternate game for two-district states like Maine, where two districts are created by players who alternate adding precincts. To be politically viable, such a game must:

- follow simple rules,
- create compact and continuous districts, and
- Not admit a dominant strategy for either player.

The effectiveness of this game is analyzed using simulated state maps and players programmed to follow simple strategies. It is shown that the game creates compact and continuous districts and does not admit a dominant strategy unless one party has a significant electoral advantage in the state.

NEW ENGLAND SOUTHERN

Gene Expression Meta-Analysis Identifies Novel Cell Type Specific Pathways in Multiple Sclerosis

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Over 2 million people suffer from multiple sclerosis (MS), a severe neurodegenerative disease with life-debilitating symptoms and an economic burden of over 85 billion dollars per year in the U.S. alone. Despite being one of the most common autoimmune and neurodegenerative diseases, the biological causes behind MS are still unknown. Diagnosing and treating MS are imperative, but due to the absence of MS-specific biomarkers and therapeutic targets, tests and drugs are ineffective or nonspecific with poor patient outcomes. Studies that address this problem by profiling the gene expression landscape produce inconsistent results. To address this issue, a robust meta-analysis of gene expression data was undertaken to provide an unbiased cell and tissue type analysis of differentially expressed genes and dysregulated pathways. This analysis elucidates cell-type specific effects and identifies a novel list of potential drug targets and biomarkers. Among these, post-translational modification, ribosomal, and mitochondrial mechanisms were found to be disrupted, implicating a new etiology that significantly expands the current knowledge of this disease. This study represents a major step in both understanding and outlining further targeted research into MS. The computational pipeline produced is capable of maximizing the biological accuracy of gene expression analyses and satisfies an unmet need in current research.

The Effectiveness of a Standardized Mixture of Antioxidants as a Preventative Treatment for PTSD and its Symptoms in *C. elegans*

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Antioxidants can be used to help prevent neurodegeneration and reduce reactive oxygen species (ROS) associated with Post traumatic Stress Disorder (PTSD) in a *C.elegans* model. 1/11 people are diagnosed with PTSD and this number is increasing. PTSD affects everyday life, since flashbacks and nightmares may occur at any time, causing a fight or flight or avoidance reaction. Previous studies have shown a link between oxidative stress and PTSD, as well as that antioxidants can reduce oxidative stress caused by reactive oxygen species. It was predicted that if the natural substances work, then the ROS of the test group and their avoidance behavior (movement backwards) caused by a trigger molecule should be similar to non-PTSD worms. The N2 *C. elegans* strain was put through an avoidance assay to simulate PTSD by having a trigger molecule: diacetyl. The antioxidant mixture was mixed with LB and E. coli, and then plated as a food source on growth medium. ROS was measured using the LD1171 strain put through the same conditioning, a fluorescent microscope, and Image J software. The 32˚C & diacetyl group that had antioxidants in their food source avoided a statistically smaller average amount of diacetyl drops compared to either control group without diacetyl present in the conditioning, and the LD1171 worms conditioned and treated also expressed less GFP. This study lays the groundwork for investigating the relationship between associations and PTSD, and future actions include investigating epigenetics to see if PTSD behaviors and ROS expression will reoccur in the offspring.

Artificial Intelligence Image Detection with GIS Multi-Layer Topological Analysis: A Twofold Approach to Lung Cancer Diagnosis

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CT and MRI scans inaccurately identify 5 out of 100 lung tumor boundaries that potentially result in metastatic disease. Late diagnosis hinders treatment and survival. This research examined the use of image detection and Geographic Information System (GIS) techniques to differentiate benign versus malignant lung tissue. A novel model was implemented to utilize both image detection and GIS techniques. MRI & CT scans of the thoracic cavity from the Lung Image Database Consortium and Image Database Resource Initiative (n=1,223) were used and round truth annotations were included. To build the R-CNN model, Matplotlib, numpy, opencv, Pillow, and scipy were used to perform image preprocessing and AI model training. A 3D GIS model and common coordinate framework was built in order to improve the convenience of diagnosis and build a topology. Noise reduction and topological analysis were performed by implementing spatial autocorrelation and Anselin Local Moran's I through cluster and outlier analysis. The GIS model helped to detect clusters, representing the tumors and vasculature. The image detection model achieved 68.6% accuracy and 72.7% recall score for detection of malignant lung tissue. With the inclusion of the GIS approach, the model resulted in 80% accuracy, an improvement of 11.4% from the AI model. The GIS model analyzed the relationship between tumor formation and vasculature, which may increase the percentage of patients diagnosed at an earlier, more treatable stage and also have applications for research in fields such as angiogenesis.

Detailed Binary Evolution Modeling: Comparing COSMIS and MESA

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The study of the evolution and formation of binary star systems is an instrumental component to both interpreting gravitational wave observations and predicting the fate of binaries in the universe. Rapid binary

population synthesis codes like COSMIC are often used to model and simulate binary star systems. However, these codes usually simplify the complexity of stellar and binary physics by interpolating single-star evolutionary tracks. The more detailed stellar evolutionary code MESA is considered a state-of-the-art modeling code that addresses caveats and inaccuracies of traditional population synthesis codes, like COSMIC.

This paper compares binary star system results predicted by rapid binary population synthesis code COSMIC with those predicted by MESA binary evolution models.

This comparison presents a novel application of comparing MESA and COSMIC simulation results. We discover that COSMIC allows for more survival of common envelope evolution and simulates binaries with larger initial radii which contributes to more unstable mass transfer. We also discover that MESA tends to produce black holes through a different evolutionary process than COSMIC. We conclude that comparing COSMIC and MESA provides deeper understanding in binary evolution.

My research will contribute to the movement in making binary star simulations more accurate and will allow for the making of more robust gravitational wave merger interpretations and predictions.

NEW JERSEY NORTHERN

SOS-PVCase: A Machine Learning Optimized Lignin-Peroxidase with Polyvinyl Chloride (PVC) Degrading Properties

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Plastic accumulating in landfills poses a major environmental threat to wildlife ecosystems and contributes to the production of harmful greenhouse gasses. Polyvinyl chloride (PVC) accounts for roughly 12% of plastic manufactured worldwide, and under current measures, nearly 79% of post-consumer PVC ends up in landfills (Geyer et al., 2017). Enzymatic degradation of plastic polymers into reusable monomers provides a green and scalable solution to this expanding problem. However, the application of PVC degrading peroxidases in real-world environments is impaired by their lack of stability and solubility (Lu et al., 2022). Fungal lignin peroxidase (E.C 1.11.1.14), an enzyme expressed by Phanerochaete chrysosporium, has previously been identified to have PVC degradation properties, but nevertheless, is also hindered by these same constraining properties (Khatoon et al., 2018). In this study, established machine learning methods in literature were used to pinpoint successful mutations in the primary structure of the peroxidase. This novel metapredictor variant approach is far more time effective than the traditional process of synthesizing each mutation in a lab, and is much less computationally expensive than other machine learning techniques. The mutant protein (SOS-PVCase: stable, optimized, soluble) contains five amino acid substitutions (A112I, A114I, S174K, E224M, L291R) and is predicted to display superior metabolic activity in various environmental conditions compared to the wild-type fungal PVCase. This is significant, as it allows PVC recycling pathways to be drastically accelerated.

Novel Stacked Ensemble Machine Learning (SEML) Model for Prediction of Viral Zoonoses

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75% of newly emerging infectious diseases, including Ebola and Rabies, are zoonotic. Originating from animals, zoonotic diseases comprise over 2 billion cases of illness and 2.7 million deaths annually. Traditionally, predicting viral zoonotic status requires laboratory experiments and field surveillance, which are time-consuming and expensive. Existing computational algorithms improve the speed of prediction, but are trained on insufficient datasets, lack feature exploration for transforming genomic sequence data, and utilize basic machine learning architectures that limit performance. This study remedies these limitations using a novel stacked ensemble machine learning (SEML) model trained on a merged genomic sequence dataset containing new feature definitions to better anticipate the zoonotic potential of viruses. The base models within the SEML model - extreme gradient boosting (XGBoost), multi-layer perceptron (MLP), and random forest - were optimized through hyperparameter tuning and balancing to avoid overfitting. Predictions generated from the base models were used to train the meta learner of the SEML model, logistic regression. Results show that the SEML model has great potential to provide reliable and robust results, improving precision-recall AUC by 80% over some previous literature's models and 10% over its base models. This novel SEML model has the potential to advance and expedite the research of zoonotic viruses.

A Novel Rotation-aware Representation Learning Procedure for Gaze Estimation to Assist Disabled Individuals in Communicating with the World Through Various Applications

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The human eyes provide an essential way of taking in visual information from the world. Fascinatingly, they can also be used to indicate a wide range of messages or emotions. Since moving the eyes requires minimal effort, even quadriplegic individuals can communicate with their eyes. Gaze estimation, the task of inferring the direction where an individual's eyes are pointed to, provides these individuals with a refined method of connecting with the world. However, gaze estimation tasks lack comfortable real-world applications because they are inherently challenging and often unreliable due to the wide variations in the characteristics of each pair of eyes. In my research, I propose a representation-learning-based training procedure incorporating a rotation matrix to increase the accuracy of gaze estimation tasks. Consequently, the proposed approach exponentiates the disentanglement of gaze-related latent features from the rest, ultimately achieving higher accuracy in more robust, harder samples. The Few Shot test results highlight an average increase of 16.5% in accuracy compared to previous state-of-the-art methods on GazeCapture dataset. Ultimately, my findings will provide disabled individuals with vast applications to more comfortably communicate with the world. For instance, my prototype of a gaze-controlled wheelchair allows paralyzed individuals to become physically independent once again.

A Novel Autonomous Vertical Take-Off and Landing Aircraft Using a Variable Thrust Control Vector and Morphing Wing Configuration System

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Mentor: Sateesh Pokkunuri

Vertical takeoff and landing (VTOL) of unmanned aerial vehicles (UAV) has many real-world applications, including intelligence, surveillance, reconnaissance, search and rescue, while extending its fly range, speed, and endurance capabilities. The goal of this study is to build a novel autonomous UAV that can perform VTOL with low weight and high payload without launch and recovery infrastructure, which is typically needed for the current aerial systems. A four-propeller variable thrust vector control aircraft was modeled and developed for improved aerodynamic efficiency to reach desirable hover height before transitioning into level flight mode. The nonlinear dynamic ailerons on the counter-rotating propellers control the angular velocity of the vehicle during the transition between hover and fly modes to minimize external disturbances and achieve attitude stabilization. A smart guidance control system is developed to expand the folded wings during hover mode to achieve the greatest power reduction and a stable transition between fly modes. Extensive experiments showed a 20% flight endurance improvement, 33.5% payload improvement, and 30% power savings between with-variable-thrust-

vector control and without-variable-thrust-vector control. The results provide evidence that infrastructure less VTOL UAV systems can be deployed in remote areas or disaster zones with substantial power reduction and increased endurance.

Efficient Deep Learning Based Video Compression

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This paper proposes a deep learning-based video compression algorithm that improves the efficiency of video transmission and storage. Every day, 1.5 billion hours of videos are watched across YouTube, Netflix, and Facebook, and 23 million new cameras are added into circulation; additionally, around 85% of all internet traffic is in the form of video data. This has resulted in an unprecedented explosion in the sheer volume of video data, occurring in the last 5 years alone. Despite this, today's methods of compressing and distributing video data are still the same as 20 years ago. This research provides a solution to the explosion in video data by documenting a novel deep learning algorithm called COMPACT that utilizes a Scale Space Auto-Encoder architecture to compress videos. This technology outperforms traditional video compression algorithms in two distinct metrics: size and quality. It produces compressed videos that are 40% smaller than its nearest competitor, H265, and still has higher reconstruction quality. Moreover, the reconstructed video quality using COMPACT is 5 DB higher in Peak-Signal-To-Noise-Ratio and 0.15 better in Multi-Scale Structural Similarity Index Measure than H265. Implementing COMPACT in the real world could significantly enhance the fields of online conferencing, video streaming, the medical industry, and video surveillance. Hence, proving the efficacy of deep learning-based solutions in the realm of video compression.

NEW JERSEY SOUTHERN

Surveying Water Surface and Wetlands in Delaware Bay Using Cloud-Removed LandSat Data

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Managing water and wetlands is critical to the environment and economy. Wetlands, marshes, and bogs in Delaware, for example, support ecosystems and provide significant economic value ranging from $1 billion to $3 billion annually, including 25,000 jobs with $568 million in wages in the state and surrounding region. However, traditional surveys are costly and time-consuming; they are often only conducted every 10-15 years. This project proposes a cost-efficient, digital solution to monitor and analyze water and wetland changes using LandSat satellite images collected by the United States Geological Survey (USGS). Missing pixels due to cloud coverage is a critical issue in image-based analysis. The project applies data imputation methods to address this problem. Then, linear and radial regressions are performed to investigate long term trends of rising sea level, decline of wetlands, and seasonal changes in Delaware Bay from 1990 to 2021. To improve the accuracy of the models, the linear regressions are extended to Support Vector Regression (SVR), a machine learning algorithm, to estimate water area as a function of time and tidal height. Tidal height information is collected from the National Oceanic and Atmospheric Administration (NOAA). Last, LandSat-based shoreline analysis is performed to identify possible erosion and accretion over the years. This method is applied to a case study of Cumberland County in NJ, ranked eighth for greatest coastal erosion in the US. This novel water monitoring framework supports governments and agencies to better manage resources, provide jobs, and mitigate risks due to environmental and climate changes.

Application Regolith of Lemna Minor for In-Situ Phytoremediation of Perchlorate in Martian

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The overall cost, complexity, and risk of a crewed deep space mission can be reduced and mission time extended by producing life support consumables utilizing local planetary resources. This approach is called ISRU (in-situ resource utilization), and one method that is shown effective for a Martian landing is growing crops using Martian "soil" (regolith) as a growth medium. However, a toxic chemical—calcium perchlorate exists in the regolith, rendering any crops grown in the regolith inedible. Perchlorate can be removed from the regolith by rinsing it with water. However, water is a critical resource in a deep space mission and must be reclaimed to make soil rinsing viable. The Air Force Research lab has shown in a 2002 study that numerous wetland plants, including Lemna Minor Duckweed, a plant attractive for a Mars mission due to its asexual reproduction and hardy nature, can remove perchlorate from contaminated materials through phytoremediation. However, the study only evaluated duckweed in tandem with other plants, leaving its ability to remove perchlorate uncertain. This study aims to determine if duckweed alone can lower perchlorate concentrations of water contaminated by Martian regolith from areas of varying perchlorate concentrations. Martian regolith was simulated by preparing regolith simulants with varying concentrations of calcium perchlorate before rinsing with water and placing the contaminated fluid in duckweed bioreactors. The concentration of perchlorate was measured over a week. A linear regression t-test was run with the condition $\beta<0$ to determine if there was a significant negative correlation between days in a.

Cloud Enabled IoT Based Alert System for Aged, Blind & Disabled Individuals

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Recent advances on the Internet of Things (IoT) platform and cloud computing-based application devices continue to revolutionize our lives, from telemedicine to automated home support, by transmitting data to healthcare providers or third-party medical alert service providers using smart wearables and SOS buttons. However, no known configurable, reliable, easy to use and cost-effective alert system is available for limited mobility individuals to promptly notify their primary caregiver by the press of a button in case of an emergency or non-emergency situation.

The objective of this project was to design and develop a low cost and easy to use cloud-enabled IoT based alert system that can be used by impaired individuals to notify primary and secondary caregivers via text message with 1-click while they are alone at home or without access to a phone.

The solution was developed using the Wi-Fi programmable IoT button. The key cloud services used were AWS IoT 1-Click, Amazon DynamoDB and AWS Lambda functions. Once the button was pressed, an event generated in AWS Lambda caused a process in AWS Step Functions to update Amazon DynamoDB with alarm activation. Amazon PinPoint then sent text message(s) to the caregiver(s).

Experimental results showed that the intended primary caregiver received notifications within 60 seconds after the button was clicked. If text was not acknowledged within 60 seconds by the primary caregiver, then the device instantly alerts the secondary caregiver. Amazon Web Services (AWS) was chosen since it provided low operational cost to reliably run infrastructure.

Comprehensive Cyber Defense System: A Look into Adaptive Protection for the Most Common Ransomware Attacks

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Mentor: Hirsh Guha, Princeton University

In this paper, we propose an adaptable solution that encompasses the protection for the most common ransomware types. In each type of attack, several mechanisms that carried out a successful attack were tested on Kali Linux-based virtual machines (VMs) and potential vulnerabilities were observed. We carried out four of the most common attacks on these VMs without any protection. After looking at how each attack ran, we examined systems that worked to combat each type of attack and noted similarities between solutions. Finally, we combined defense mechanisms and tested these combinations to ensure adaptability and fail-safe mechanisms across several attack types. Through experimentation with multiple attacks and defenses, we not only observed how each attack was prevented when its corresponding defense was installed, but we also took note of the impact that each defense had on the other attacks. In doing so, we were able to determine the defense that was the most comprehensive for the attacks tested. In this context, a comprehensive defense is one that is able to provide substantial protection against a subset of attacks. In later experiments, we tested all possible combinations of the defenses and found an optimal combination that successfully combated all examined attacks. We wrote code (https://github.com/riyapawar/ccds) that automates the process of installing each defense onto Linux machines.

Analysis Of Tannin Interference on Enterolert* 250 Testing of *Enterococcus*

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The IDEXX Enterolert* 250 Test Kit is designed to indicate the presence of *Enterococcus* and, when used with the Quanti-Tray®/2000 System, can provide a most probable number (MPN) of bacteria. It is important to obtain accurate testing of *Enterococci* because it is known to provoke a multitude of health issues in humans. Previous testing utilizing the IDEXX methodology resulted in abnormally high MPNs which led this study to explore the idea of tannin interference with the chemical indicators of the test. Using various concentrations of tannic acid and *Enterococcus* water samples, it was discovered that a positive exponential relationship exists between increasing tannin concentration and increasing MPN. Further research resulted in a hypothesis regarding the confusion between phenol groups of tannic acid and nitrates of the Enterolert* substrate to account for the false positives. The findings of the experiment supported the hypothesis that high tannin concentration causes an excess of false positives in the Enterolert* test. The discovery of tannin interference in this testing is important to understand the reliability of the technique and investigate possible effects of tannins on other phenol-based water quality tests. It is vital for the safety of the environment to prevent the use of unreliable methods and prevent remediation overcompensation.

*Enterolert is a trademark or registered trademark of IDEXX Laboratories, Inc. or its affiliates in the United States and/or other countries

Improving Doxorubicin-Chemotherapy Treatment with Luteolin and Resveratrol: A Novel Synthetically Engineered Secondary Metabolite TDB-13

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Teacher: Dr. Allyson Weseley, Roslyn High School

First-line chemotherapy drug doxorubicin, the most potent chemotherapy drug to date, is used in virtually all chemotherapy treatment plans. 92% of cancer patients are treated with chemotherapy yet for the past six decades, chemotherapy has had a failure rate of 90%. An overwhelming majority of the failures are attributed to the side effects of doxorubicin. No existing treatment exists that mitigates doxorubicin's repercussions without significantly depleting its therapeutic efficacy.

No research has tested any secondary metabolites on any chemotherapy drug. To evaluate therapeutic efficacy: luteolin, resveratrol, and doxorubicin treated *in vitro* models of carcinoma (80-90% of all cancer cases) alone and as a trio. To test the side effect of cardiotoxicity: *in vitro* models using cardiomyocytes were developed. The mechanisms of action were found through in silico computational binding.

Results of luteolin and resveratrol alone indicate that though they are therapeutic to in vitro carcinoma cells, there is one weakness: a small therapeutic window (concentrations of 15μM and 20μM being equally or less effective as the lowest concentrations of 5μM and 10μM) — suggesting that while luteolin and resveratrol have increased in popularity (in the form of dietary supplements) among cancer patients by 82% since 2010, the compounds may not always produce the desired effect. Combining luteolin and resveratrol with doxorubicin was able to improve therapeutic efficacy of doxorubicin while reducing cardiotoxicity. By methylation and glycosylation of both luteolin and resveratrol, a novel compound "TDB-13" was able to maintain the level of therapeutic efficacy and reduction of cardiotoxicity while lengthening.

Evaluating the Effect of SPTBN1 Knockout on Pyruvate Kinase Molecule 2 Expression and Hepatocellular Carcinoma Development

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Hepatocellular carcinoma (HCC) accounted for an estimated 660,000 deaths in 2020, and the prevalence of HCC is expected to increase by over 55% between 2020 and 2040. Due to the lack of an effective treatment for late-stage HCC, the five-year survival rate is less than 20%. Pyruvate kinase molecule 2 (PKM2) and pyruvate kinase molecule 1 (PKM1) are rate-limiting enzymes that mediate the last step of glycolysis, catalyzing the breakdown of phosphoenolpyruvate into pyruvate. PKM1 is highly expressed in terminally differentiated, non-proliferating cells while PKM2 is highly expressed in proliferating embryonic cells. Upon PKM2 upregulation, cancer cells reprogram their host's metabolic pathways, increasing glucose uptake and evoking fermentation of glucose to lactate, a phenomenon known as the Warburg Effect. This altered metabolism allows rapid production of ATP, promoting cancer cell proliferation. This study found that liver-specific knockout of the SPTBN1 gene significantly decreases PKM2 levels and prevents inflammation, cell proliferation, and abnormal vascular development. Immunohistochemical (IHC) staining with the PKM2 antibody was performed on paraffin-embedded liver tissue slides from wild-type (WT) mice, WT mice chemically induced with HCC, and HCC mice that had the SPTBN1 gene knocked out in the liver. After IHC staining, the tissue slides were photographed under a light microscope and analyzed in ImageJ, where PKM2 expression was calculated. Results of the IHC staining were also used to assess the severity of symptoms in each group of mice. This study found evidence suggesting SPTBN1 targeted gene knockout therapy may ameliorate HCC-induced symptoms and inhibit HCC development.

The Annotation of Novel Datasets for the Training of *Cellori (Cell Origin) Spots*, a Deep Learning Algorithm for RNA FISH Spot Detection

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Mentor: William Niu, University of Pennsylvania

Developments in microscopy imaging have allowed for in depth study of biological systems at a level never previously reached. One such method is RNA fluorescence *in situ* hybridization (FISH), which is commonly used to visualize the spatial and temporal expression of specific genes within cells. Analysis of large datasets can be cumbersome and time consuming, especially when assessing fluorescent localization manually. Attempts have been made to automate this process such as *TrackMate* which makes use of the Laplacian of Gaussian (LoG) operator. A Gaussian Blur is used to normalize background noise. The Laplacian operator is applied to increase contrast between the background and true spots. LoG requires a manually specified intensity threshold to determine the presence of a spot. The ideal threshold varies across datasets, images and even within different regions of the same cell. Although LoG increases annotation efficiency, its performance and efficiency are limited by a researcher's ability to set an accurate threshold. Developments in deep learning have led to automatic algorithms for RNA FISH spot detection. However, current deep learning algorithms fail to perform on datasets without uniform spots and low background noise. In this research, a novel deep learning algorithm, C*ellori (cell origin) Spots* was developed for the automatic quantification of RNA FISH. As a result of a custom architecture, custom loss function, and novel training dataset, *Cellori Spots* is able to outperform LoG and current deep learning approaches to RNA FISH spot detection across a variety of image types.

Palindromes and Promoters: The Importance of Palindromes in DNA Sequence

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A palindrome is a word or phrase that can be read the same forward and backward. Similarly, palindromic sequences in DNA can be read the same from the 5' to 3' end on one strand as on the reverse complement strand (Smith, 2008). These sequences frequently occur near transcription factor binding sites (Qian et al., 2006), and this study aimed to determine whether they also occurred more often near promoters, enhancers, and other key regions of the genome. I deployed an algorithm on the genome of *C. elegans* to calculate the overall palindrome richness throughout the genome and identify extremely palindrome-dense areas. The findings indicate that palindromes have biological significance in the *C. elegans* genome, as they occur significantly more often than expected under a randomized model. In addition, intergenic regions were found to be the most palindrome-dense in the genome, indicating that palindromes may indeed occur more frequently in close proximity to promoters and enhancers.

Analyzing Cellular Pathways to Understand SARS-Cov-2 Related Cardiomyopathy Through Differential Expression Analysis of Single Cell Transcriptomic Data From Infected Human Ipsc-Derived Cardiac Cells

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SARS-CoV-2 infection can cause widespread dysfunction across multiple organs, including the heart. Myocardial dysfunctions have been observed in many patients with COVID-19. To understand whether COVID-19 can lead to long-term heart disease, I studied transcriptomic profiles from SARS-CoV-2 infected cardiac cells derived from healthy human subject induced pluripotent stem cells (hiPSC). I analyzed four distinct lines of hiPSC derived cardiac cells, uninfected and infected with SARS-CoV-2 in the presence and absence of interleukins (ILs). An integrated data set for the hiPSC's from all cell lines was clustered by comparing clusters with cells from healthy adult human heart tissue and identified fibroblast-like and ventricular cardiomyocyte clusters – abundantly found cells in the heart. To understand how SARS-CoV-2 affected gene expression, differentially expressed genes (DEGs) for both cell types between control and SARS-CoV-2 infected cells with and without interleukins (ILs) were calculated. Enrichment analysis on these DEGs identified the dysregulated subcellular pathways (SCPs). SCPs from SARS-CoV-2 infected fibroblast and cardiomyocyte cells were then compared with pathways of corresponding cell-types from the hearts of patients who had dilated and hypertrophic cardiomyopathy. Substantial overlap was found. Specifically, SCPs underlying cellular adhesion, and protrusion dynamics were dysregulated in fibroblasts and energy generation and cellular contraction were dysregulated in cardiomyocytes. The similarity of top ranked pathways dysregulated by SARS-CoV2 infection and cardiomyopathy suggest that COVID-19 can produce changes that could lead to heart failure over time. While most people recover from COVID-19 fully, for some, persistence of these cell-level changes could lead to long term heart disease.

Bézier Curve Method to Compute Various Meniscus Shapes

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The question of the meniscus shape, or the boundary of a liquid, has long been an unsolved problem in theoretical physics. The problem holds significance because menisci appear in a variety of contexts, from lava lamps to capillary action to membranes. The Young-Laplace equation, a differential equation, determines the meniscus shape. Although numerous works have attempted to solve the equation, or approximate its solution, they all involve complex techniques and tedious computation. This paper demonstrates an elegant solution to the meniscus shape problem using the Bézier curve method: it fits a Bézier curve to the Young-Laplace equation to approximate its solution. To test the Bézier curve method's viability, this paper uses it to solve four cases of menisci: liquid in a cylindrical tube, against one plate, against two plates, and in a water droplet. In each case, the accuracy and complexity of the Bézier curve method are analyzed, and the results are compared with those of previous works. The Bézier curve is usually used in the field of computer graphics, as opposed to science, and has never been applied to the meniscus shape problem before. The Bézier curve method is a novel, simple, and accurate technique to solve the meniscus shape problem, and the success of the Bézier curve method here suggests that it could also help solve a variety of other scientific problems.

Creating Superresolution Spectra from Titan's Equatorial Dunes

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Mentor: Dr. Paul Corlies, Massachusetts Institute of Technology

Titan, a moon of Saturn, is the most Earth-like body in the solar system. Titan hosts lakes, dunes, craters, and an atmosphere, which means that Titan is an Earth-like environment. NASA sent Cassini to observe Titan more closely. Onboard Cassini, the Visual and Infrared Mapping Spectrometer (VIMS) was used to measure Titan's surface composition in infrared wavelengths. Infrared wavelengths are necessary, as the atmosphere obscures all visible light. However, systematic instrument error caused the peak sensitivity wavelength value of each VIMS channel to shift. In other words, there was an increasing calibration gap between the wavelengths it was measuring and the wavelengths it was designed to measure. This study focuses on the development and implementation of a technique to leverage this behavior to create a higher-resolution spectrum of Titan's equatorial dunes. The technique involves removing the effect of the atmosphere on the data, and then applying all the shifts of the spectrometer to the dataset. Even without being able to remove the effect of the atmosphere on the data, the results still showed a fivefold increase in the resolution of VIMS. This shows promise for future correction algorithms.

Analyzing Synaptic Boutons in Layer 3 of the Primary Visual Cortex in the Human Brain

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Mentor: Dr. Virginia Garcia-Marin, City University of New York at York College

In the time it takes you to read this sentence the neurons in your brain have made billions of synaptic connections. The brain consists of 86 billion cells called neurons that make synapses every second to communicate with each other. The brain is home to the central nervous system which controls the inner workings of the human body. Synaptic activity is essential for the function of the brain and the human body. We studied the synaptic morphology in the primary visual cortex, located in the occipital lobe, intending to relate their morphology with their physiology or synaptic activity. This part of the brain is the visual association area which grants us vision. Focusing on layer 3 of this area we utilized 3D reconstruction to build models of the presynaptic axon their mitochondria and their synapses. Our research goal was to understand how the morphology of these boutons (axons) impact the synapses produced in layer 3 of the Primary Visual Cortex. We concluded that there is a significant difference between the volume distribution of boutons based on the presence and absence of mitochondria, there is a positive relationship between mitochondria volume and bouton volume, and lastly, there is a positive relationship between bouton volume and PSD (synapse) volume. Through this research, we hope that an in-depth understanding of the relationship between the anatomical structures of neurons and their synapses can guide scientists to generate realistic models of the primary visual cortex, and possibly guide treatment for synaptic recovery following occipital injuries.

NEW YORK–UPSTATE

Investigating Plastic Remediation: Rational Protein Engineering of Petase From *Ideonella sakaiensis* to Stimulate The Bioremediation Of PET Pollution

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Mentors: Dr. Danielle Tullman-Ercek and Dr. Carolyn Mills, Northwestern University

Despite vigorous recycling efforts, nearly 350 million tons of polyethylene terephthalate (PET)—plastic commonly used to package foods and beverages—accumulate annually, posing a serious threat to global ecosystems. To combat this accumulation of plastic pollution, the biological treatment of plastic waste has become an important research focus. This process uses microorganism-derived enzymes to breakdown PET so that new plastic polymers with desirable properties can be sustainably reassembled. Though many hydrolase enzymes can depolymerize plastic, PETase from the bacterium *Ideonella sakaiensis* (*Is*PETase) is the most promising of these enzymes because of its remarkably high degradation efficiency at moderate temperatures. However, *Is*PETase's durability and efficiency must be further improved before its ability to serve as a principal recycling strategy can be realized.

By utilizing Protein Repair One-Stop Shop (PROSS)—a novel structure-based bioinformatics tool—IsPETase variants with both improved thermal stability and degradation efficiency were developed. Specifically, four unique IsPETase variants were designed and assessed to determine if the PROSS algorithm could effectively improve their stability. In the end, all four variants exhibited higher thermal stability than the wild type, with the most remarkable increase in stability having been demonstrated by variant 3—with a 7.5° increase in melting temperature. As this is the first study to solely rely on the PROSS algorithm to optimize the stability of *Is*PETase, this study identifies an exciting new route for developments in protein stability. Further, by gaining this valuable insight into *Is*PETase's stability, we are closer to developing an effective treatment for pollution.

Developing Environmental DNA Metabarcoding for the Detection of Elusive Vernal Pool-Breeding Amphibians

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According to the IUCN Red List, 41% of amphibian species worldwide are threatened with extinction. Conservation efforts for amphibian populations are limited as traditional biomonitoring methods fail to accurately census elusive species. This study developed a passive biomonitoring technique, using environmental DNA (eDNA) metabarcoding to target two elusive pool-breeding salamander species, the Jefferson salamander *(Ambystoma jeffersonianum)* and the blue-spotted salamander (*Ambystoma laterale)*, as well as the ubiquitous wood frog species *(Rana sylvatica)*. Aquatic eDNA was extracted from 102 periodic water grabs from four vernal pools and four brooks/streams in the Hudson River watershed between February to May in 2021 and 2022. The vertebrate 12S rRNA mitochondrial gene was amplified, sequenced, and matched to our novel DNA reference sequences for spotted salamander *(Ambystoma maculatum)* and Jefferson salamander *(Ambystoma jeffersonianum)* and GenBank nucleotide data. eDNA metabarcoding detected 63 vertebrate species, including ten amphibian species, along with multiple elusive amphibians: Ambystoma jeffersonianum-laterale complex, spring peeper *(Pseudacris crucifer)*, two-lined salamander *(Eurycea bisleanata)*, and spotted salamander *(Ambystoma maculatum)*. Between the two wetland types surveyed, vernal pool obligate detections were highly specific to vernal pools (95.6%; $p < .001$), reinforcing eDNA as a proxy for observed species' presence. The lack of vernal pool protections underscores the urgency for monitoring methods that accurately census elusive species, and the results of this study demonstrate the viability of eDNA metabarcoding as a novel amphibian monitoring technique and its broad applications for the conservation of threatened species.

Electron Transport Chain Acts as Potential Regulator of ER-Mitochondria Interactions

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Mitochondria are highly dynamic organelles that interact with various cellular components, including the endoplasmic reticulum (ER). This essential interaction occurs through mitochondria-associated membranes (MAMs) to carry out key processes such as phospholipid trafficking. However, the effects of mitochondrial dysfunction, specifically within the electron transport chain (ETC), on mitochondria-ER interactions are not fully understood. To investigate how perturbed bioenergetics impact MAM activity, phospholipid trafficking and synthesis were assessed, in which the conversion of phosphatidylserine (PS) to phosphatidylethanolamine (PE) was analyzed after inhibiting ETC complexes. Using two human cell models—fibroblasts with a mutation on the nuclear gene NDUFS4, interrupting complex I of the ETC, and a human osteosarcoma cell line (143B cells) treated with ETC inhibitors and uncouplers—it was found that inhibition of ETC complexes I, III, IV, and V results in a significant lack of conversion between PS and PE ($p < .0001$), demonstrating altered MAM activity due to mitochondrial dysfunction, and indicating that the ETC is a regulator of such interactions. However, inhibition of complex II, which has no effect on mitochondrial membrane potential (MtMP), was observed to have no impact on MAM connections, suggesting that MtMP may also regulate ER-mitochondria contact sites. The findings of this research contribute to the understanding of how ETC dysfunction impacts inter-organelle crosstalk, providing new insights into the pathophysiology of mitochondrial disorders and a greater understanding of the dynamic role of mitochondria in cells.

Examining How Perceptions of Privilege and Anti-White Bias Correlate with Levels of Racial Trauma in White American Adults

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In an increasingly tumultuous and tense political and racial climate, there is new information in the concept of racial trauma. Racial trauma is a direct effect of personal experience or exposure to race based discrimination and therefore, affects those who experience racial discrimination. This study aims to investigate the factors associated with White American adults who report perceiving race based discrimination or Anti-White Bias (AWB). The study employs a survey sent to Marist students and a convenience sample ($n=153$) that utilizes questions from the Gallup Poll Race Relations Historical Trends, the Trauma Symptoms of Discrimination Scale as well as my own original questions concerning ratings of privilege/oppression of the respondents own race and their perceptions of others. The results demonstrated that there were White participants who reported Anti-White bias that had specific perspectives, including being more conservative, being more satisfied with race relations and reporting less worry about race relations in general. The results of this study indicate that there are clear divides in perceptions concerning race when considering different racial groups and political party affiliations. Future research further investigating these trends may find significant correlation with exposure to different education about race.

A Universal and Adaptable Autonomous Unmanned Ground Vehicle for the Inspection and Monitoring of Electrical Substations

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Power grids, necessary for the distribution of power that billions rely upon, are encountering a growing number of threats from climate change, extreme weather events, and aging infrastructure. There is a strong need for more modernized electrical grids which utilize monitoring technologies in order to improve the efficiency of grid operation while preventing injuries. In recent studies, robotic systems have been employed in electrical substations to increase the efficiency, safety, and reliability of grid maintenance. Thus far, however, few substation monitoring robots have shown the necessary partial discharge (PD) detection abilities, navigation and manipulator accuracy, adaptability and versatility. I worked to develop an Unmanned Ground Vehicle (UGV) for substation monitoring with the appropriate accuracy, flexibility, and autonomy for the maintenance task. The robot's novel design was tested in three computer simulated environments meant to mimic real-world substations and in two real-world environments: a robotics lab and an electrical substation. The robot successfully, autonomously, and efficiently completed the necessary tasks. The first use of a simultaneous localization and mapping algorithm to navigate throughout the substation as well as the integration of a fusion of sensors made the novel UGV far more versatile and adaptable than its predecessors, and the overall system showed improved situational awareness, perception, and inspection capabilities crucial for the dynamic substation environment.

NORTH CAROLINA

Determining the Influential Properties for Targeting RNA Secondary Structures with Small Molecules

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Purpose: RNA structures are known to have implications in diseases and serve as a potential therapeutic target. One method for targeting RNA is using small molecules. RNA secondary structures create binding sites that allow small molecules to bind to RNA. Small molecules have been found to have properties that make them favorable for RNA binding, however, these properties are still being discovered. This research aimed to determine the small molecule properties favorable for RNA binding using a set of small molecules with different properties compared to other known small molecule RNA binders to evaluate if they would bind and the properties that influence their binding.

Method: RNA titration was performed to determine each RNA structure's KD with an indicator. A small molecule indicator displacement assay was performed, and the percent displacement of each small molecule at various concentrations was obtained. The small molecule properties were then analyzed using a principal component analysis.

Results: It was found that none of the small molecules showed a positive percent displacement trend for either of the RNA structures and that the properties of the small molecules had an equal contribution to the variance in the principal component analysis.

Conclusions: These experiments show that none of the chosen small molecules bound and, as expected, none of the small molecule properties were influential in the binding interaction.

Designing an Activated Carbon Filter to Reduce Water Contamination from Fire Water Runoff

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Mentor: Dr. Coleman Bailey, Charles D. Owen High School

During many industrial fires, the chemicals released from the incineration of materials inside the building and ones commonly used by firefighters to extinguish the fire are often picked up by water and transported to the nearest storm drain. Fire water runoff (FWR) entering the water supply has been shown to cause significant harm to aquatic ecosystems and human health. The most dangerous of these chemicals are per- and polyfluoroalkyl substances (PFAS). Exposure to PFAS is linked to reproductive effects, developmental effects, and cancer. Firefighters commonly use aqueous film-forming foams (AFFFs) to extinguish fires at sites like airports, military bases, chemical plants, and refineries. It is shown to contain PFAS and is in the process of being regulated, but it is still used in many states in the United States, including North Carolina. Due to a significant portion of FWR entering the water supply through storm drains, I am designing a filter, which is a woven cotton sock filled with granular activated carbon (GAC) to adsorb pollutants, including PFAS. It will be designed to quickly deploy around a storm drain during a firefighting emergency for FWR to flow through. My hope is that this project has future applications for use by firefighters to protect our water supply and keep marine life and humans safe from toxic pollutants.

Caenorhabditis elegans as a Model for the Effects of Stress on Transgenerational Psychological Disorders

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Generational trauma is generally viewed as a social and psychological issue, but prior research shows that there could be a biological component as well. This experiment observed the link between stress, the presence of depression risk genes, and depression symptoms. Three strains of *C. elegans* were used, two that express depression risk genes *mod-5* and *sad-1*, and a wildtype. Ethanol was used as a stressor, and the expression of serotonin sensitivity and suicide phenotypes were measured in unstressed and stressed groups of each strain. Phenotypic expression in non-stressed offspring was observed to see if they inherited the phenotypes and behaviors displayed by the parent generation. A positive but non-significant correlation exists between having parents expressing a suicide and serotonin sensitivity phenotype due to ethanol exposure and offspring expressing this same phenotype, especially in groups expressing depression risk genes that were predisposed to showing behaviors associated with major depressive disorder. This research provides a new understanding of the causes and inheritability of major depressive disorder, has applications in the treatment of psychological disorders such as major depressive disorder, anxiety, obsessive-compulsive disorder, and alcoholism, provides new ideas about predisposition to mental health issues, and suggests there is a biological aspect to generational trauma.

Flexible Hybrid PVTTENG: Photovoltaic-Thermoelectric-Triboelectric Nanogenerator for Self-powered Systems and Blue Energy

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With carbon emissions and energy demands at an all-time high, recovering wasted energy at a low cost has become increasingly significant. Renewable nanogenerators currently being researched include piezoelectric, thermoelectric, triboelectric, photovoltaic, etc. Given the human body's potential to harvest up to 67 watts of energy, self-powered systems can be integrated into wearable electronics and other implants to remove the need for small batteries. Rather than a material science approach, this study focuses on optimizing a hybrid system that simultaneously harvests energy from different mechanisms. Photovoltaics convert photons into energy relatively effectively but are weather dependent. Thermoelectric generators (TEGs) convert temperature differences into energy, however, are known to be relatively inefficient, non-flexible and toxic as most contain dopped bismuth telluride (Bi2Te3). Triboelectric nanogenerators (TENG) convert mechanical energy into electricity, but they are not continuous. In this study, two effective paper-based hybrid photovoltaic-thermoelectric-triboelectric nanogenerators (PVTTENGs) are fabricated to optimize the advantages of the three energy systems: Photovoltaic effect, Seebeck effect, Electrostatic induction/Triboelectricity. Engineering goals include fabricating a device that is low-cost, non-toxic, printable, and flexible. One method creates a multilayer printable PVTTENG (PEDOT:PSS/Graphite) that achieves all engineering goals. While the other represents a single layer "commercial" PVTTENG with a greater voltage potential. It is concluded that both designs for the PVTTENG are more effective than single-energy systems. Additionally, from the results, it is implied that the multilayer PVTTENG could be more applicable to industrial blue energy applications, while the single layer could be applied to wearable electronics in self powered systems.

Improving Bitcoin's Post-Quantum Transaction Efficiency with a Novel Lattice-Based Aggregate Signature Scheme Based on CRYSTALS-Dilithium and a STARK Protocol

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Quantum computing is revolutionizing cryptography, but it will render the classical digital signature schemes such as ECDSA (Elliptic Curve Digital Signature Algorithm) insecure. Therefore, post-quantum schemes are developed to protect Bitcoin's post-quantum security. However, the large signature sizes of these existing post-quantum schemes cause Bitcoin's post-quantum transaction efficiency to significantly decrease, which will be detrimental to the $331.6 billion Bitcoin industry. In this research, a novel lattice-based aggregate signature (LAS) scheme is crafted to improve Bitcoin's post-quantum transaction efficiency, and it is based on CRYSTALS-Dilithium, the primary post-quantum signature scheme selected by the National Institute of Standards and Technology, and a zero-knowledge Scalable Transparent Arguments of Knowledge (STARK) protocol. With compactness, correctness, and unforgeability proofs, the proposed scheme shows Strong Unforgeability under Chosen Message Attacks in the Quantum Random Oracle Model. Not only does it generate small signatures, but the scheme also takes advantage of Dilithium's Number Theoretic Transform for easy implementation, STARK's zero-knowledge proof to protect traders' privacy, and a novel aggregation method to prevent rogue attacks. Implemented in Python, the proposed LAS scheme demonstrated its considerable advantages over other schemes: the proposed scheme improves Bitcoin's post-quantum transaction efficiency by 6 times from Dilithium, allowing 1087 transactions per block (tpb) as opposed to Dilithium's 159 tpb. The proposed LAS scheme surpasses the transaction efficiency of other known LAS schemes by a significant degree, and it will be crucial to Bitcoin once quantum computers are popularized. Furthermore, this LAS scheme can be modified to improve other cryptocurrencies' post-quantum transaction efficiency.

NORTH CENTRAL

Face Your Fears: Creating A System to Study How Mice Overcome Their Fears

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Fear is an evolutionary mechanism developed to protect animals from harm but they must also be able to overcome that fear under the right circumstances. Although there has been testing to see how animals react in fearful situations, there hasn't been much research into what occurs in their brains as they attempt to overcome these fearful encounters. We created a semi-realistic, mock predator to startle food-deprived mice as they attempt to overcome their fear to obtain a food pellet. We built an arena out of acrylic in which to perform the experiment, with a programmed trap door to regulate the movement of the mice into the arena. The arena has an open top to accommodate a mesoscope, a small camera designed to fit on top of the skulls of specially-bred mice. These mice have a fluorescent marker that lights up active areas of the brain, to facilitate tracking of brain activity during the trials. We found the food-deprived mice were significantly more likely to approach the predator than the control mice. We also found that there was not a significant difference in the likelihood of the mice approaching the predator as trials progressed. Our research can elucidate how the innate sense of fear can be overcome and could lead to better treatments for anxiety and other mental disorders.

Classifying Brain Tumors from MRI Images Using Deep Transfer Learning

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Mentor: Oscar O'Rahilly, Stanford University

Each year, more than 100,000 people in the United States are diagnosed with a brain tumor. An early and accurate diagnosis is crucial in getting patients the necessary treatment and increasing survival rates. In recent years, machine learning algorithms have become increasingly popular in the medical field due to their ability to recognize complex patterns and reduce human errors. However, accurate diagnosis using deep learning algorithms requires a large amount of training data, which is not always available. Additionally, training a model from scratch can take a long time and requires vast amounts of computational power. As a solution, this study aims to utilize a transfer learning method in which the prior knowledge of a pretrained model is used to aid in a new classification problem. In this study, a dataset of MRI images consisting of four classes (no tumor, pituitary tumor, meningioma, and glioma) were used. The performance of seven pretrained models (ResNet18, ResNet50, VGG16, DenseNet, GoogLeNet, ShuffleNet, and MobileNet) were evaluated in order to see which would achieve the highest classification accuracy. Additionally, this study examined two different methods for the implementation of transfer learning. In the first method, all layers of the pretrained model were frozen and in the second method, all layers of the pretrained model were trained. The best performing models proved to be ResNet18 and ShuffleNet with all layers trained, achieving an accuracy of 97.86%. The results also showed that the unfrozen models outperformed their frozen counterparts.

Studying the Impact of Microplastics on Quinoa Growth

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Teacher: Ms. Karissa Baker

This experiment's purpose was to determine if the presence of common microplastics (polyethylene (PE), polyamide (PA), and polyethersulfone (PES)) would impact the growth of *Chenopodium quinoa* plants. The experiment had one control group with no microplastics and three experimental groups, one for each plastic, and 10 replicates in each group. The specimens were grown in a Conviron A1000 chamber for 15 days. Microplastics were polluted at 1% volume density. The growth of the plants was measured using final growth height and biomass at the experiment's end. The *C. quinoa* specimens in the control, PA, and PES groups fared about the same in terms of final growth height ($p < 0.05$) while the PE group lagged behind. The biomass data was not statistically significant ($p > 0.05$), as all groups experienced high biomass variability and no major differences were witnessed between them. The lower growth among PE specimens was possibly caused by oxidative stress instigated by the plastic or the PE particles' high relative surface area leading to the rapid release of chemical additives. The hypothesis, which predicted hindered growth among polluted groups, was partially supported by the PE group's limited growth, but insignificant biomass data suggested more experimentation was necessary.

Bioinformatic Prioritization of the Neurotransmitter Receptor Grin2a in a Molecular Network Of Addiction

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Addiction is a disease in which the structures and function of the brain's dopamine pathways are altered, resulting in compulsive indulgence in a substance or activity. Although much progress has been made in recent years in understanding addictive behavior, its underlying mechanisms are still largely unknown. To investigate the underlying transcriptional mechanisms of addiction, we conducted a bioinformatic study analyzing data from several online databases, including GEO2R, and the Therapeutic Target Database. Through the NCBI GEO database, we identified two datasets that compared gene expression changes in control individuals and those affected by cocaine dependence. Our analysis revealed 30 genes changed within the context of both a rat and human study of cocaine addiction. Moreover, the Reactome Knowledgebase as well as the DAVID Functional Annotation database revealed the neuronal systems pathway is enriched in these inter-species datasets. When comparing our list of 30 altered genes to those involved in the neurophysiological process, we found 12 gene expression changes conserved in both rat and human studies important for neurophysiological processes. Overall, we were able to find highly conserved gene expression changes that occur in humans and rats, with 4 of these differentially expressed associated with nervous system processes.

Preposterous Proteoglycan! Defining the Role of CSPG4 in Pancreatic Cell Invasion and Spheroid Formation to Achieve Effective Immunotherapy Treatments

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Teacher: Princesa Hansen

Pancreatic cancer's extremely high mortality rate can be attributed to its high invasive and metastatic potential and resistance to traditional therapies. Chondroitin Sulfate Proteoglycan 4 (CSPG4), a transmembrane proteoglycan expressed on the surface of cancer cells, is associated with cancer cell proliferation, invasion, and survival. To determine if CSPG4 is expressed in pancreatic cancer cells and its specific function, four CSPG4 positive cell lines were screened from seven pancreatic cancer cell lines using western blot analyses. Two CSPG4 positive cell lines, PANC-1 and SW 1990, were chosen along with a negative CSPG4 cell line MIA PaCa-2, as the subjects for CSPG4 biological function study. In the spheroid formation assay, CSPG4 positive PANC-1 and SW 1990 were observed to form intact and compact spheroids, whereas CSPG4 negative MIA PaCa-2 exhibited a looser and incomplete spheroid. Next, CSPG4 specific siRNA was used to knockdown CSPG4 expression in PANC-1 and SW 1990 cells. CSPG4-knockdown cells exhibited lower capability of solid spheroid formation. Cells that underwent no treatment and control siRNA transfection exhibited normal spheroid formation. Furthermore, cell invasion assays using Matrigel coated invasion chambers were performed with PANC-1 cells transfected with CSPG4 siRNA and control siRNA. Statistics show the average invaded cells per 5 fields for CSPG4 siRNA treated cells is 52% less than that of control siRNA treated cells. These preliminary results indicate that CSPG4 is expressed in pancreatic cancer cells and its expression potentially promotes malignant progression in the cancer.

OHIO

Prefilled Syringe Testing of In-Use Hospital Drugs

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A prefilled syringe is a delivery device that ensures a safe, reliable, effortless, and dependable way to deliver a drug/medication to a patient in any setting necessary. Whether it be in an Operating Room or a hospital bed, prefilled syringes are meant to alleviate the issues of the multi-step process of manually drawing medicine from a vial with an empty syringe to then deliver to a patient. With adequate microbiological, chemical, and functional testing done on prefilled syringes one drug type at a time, at the Pharmaceutical company we focus primarily on the functional testing of the prefilled syringes to ensure their reliable use. Three machines, in particular, are used to determine the amount of forces required to push the plunger rod and twist the tip cap off of a syringe, and to ensure container closure integrity of the syringe tube itself while the drug resides inside. Four to five drug types have been tested in syringes in the past year and a half, with graphs and formal reports displaying their results. The FDA required each drug type to be tested in 3 batches of 60 syringes with their results then shared in a proper and backed-up manner so as to gain approval for the prefilled syringe's use in hospitals for that particular drug type. The force results of the 4-5 drug types tested did not exceed the maximum forces able to be twisted for the tip cap or for pushing the plunger rod, and the air vacuum test has.

Development of Novel FLT3 Inhibitors to Overcome Drug Resistant Leukemia

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Cancer is a leading cause of death worldwide, and leukemia is responsible for significant fatalities in children. The *Leukemia* and *Lymphoma Society* reported more than 23,000 deaths caused by leukemia in 2021. Current drug therapies induce cellular death through apoptosis. However, apoptosis can promote relapse and drug resistance in cancer patients, so there is an urgent need to find alternate therapies. One such option can be to find alternate mechanisms of cancer cell death. Common cancer-targeting drugs promote FLT3 (a tyrosine kinase receptor) to mutate, promoting apoptosis, relapse, and chemoresistance against the drug. The dual objective is to study the effect of FLT3 inhibition on the percentage and type of cellular death. A high-throughput screening using a library of chemical compounds identified three prominent drugs that inhibit FLT3. The effects of these three drugs on cell death mechanisms of leukemic cells were studied using a microscope and CellTiter-Blue assay. The results collected provide evidence that an FLT3 inhibitor induces non-apoptotic death. While all three compounds showed significant cell death and similar IC50 values in the micromolar range, CST-16 was found to be most effective. In addition, the CST-16 drug causes methuosis, which is a very efficient non-apoptotic method of death. Therefore, it can be inferred from past studies that there will be less cancer relapse and drug resistance. Together, it is shown that inhibition of FLT3 can be a helpful strategy in clinics to treat drug-resistant leukemia in patients in the future.

Over 60 Single Nucleotide Polymorphisms Across 8 Chromosomes are Shared by 7 Distinct Cancer Types

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Mentor: Robert Aguilar, Western Reserve Academy

Successful cancer treatment relies on understanding its etiology and the early detection of symptomatic patients. The identification of single nucleotide polymorphisms (SNPs) shared between distinct cancers can assist in furthering our understanding and may also serve as possible biomarkers. To investigate this objective, whole genome sequencing data were obtained from the Sequence Read Archive, and then analysis pipelines were constructed to map the sequences against different chromosomes followed by indexing and variant calling. To date, 8 chromosomes have been analyzed and over 60 SNPs found to be shared by 7 distinct cancers that range from breast to prostate cancer. Our analyses have identified cross-cancer SNPs that lay the foundation for future etiological studies and suggest that different cancers share common SNPs that may serve as suitable biomarkers.

DSLR Camera Photometry

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Photometry is an area of astronomy that involves measuring the magnitude of stars and other celestial objects. Traditional photometry observations require thousands of dollars of equipment and complex proprietary software, making it widely unpopular and inaccessible to amateur astronomers. The goal of this project was to determine the efficacy of inexpensive, consumer Digital Single Lens Reflex (DSLR) cameras and lenses by optimizing the process of photometry to produce the most accurate results possible with affordable and accessible hardware and software. This optimization analyzed a variety of factors, including camera sensitivity, location in the frame, focus level, exposure length, overall exposure time, and processing type. The Pleiades star cluster was analyzed for this project, chosen for its optimal positioning in the sky during testing, similar star magnitudes, and recognizability. A prototype equatorial star tracking mount was also designed and tested to examine the impact of star tracking vs manual tracking on the accuracy of photometry results. After taking a wide variety of images, the most influential factors were camera sensitivity (ISO), distance from the center of the frame, processing type, and exposure time. Other factors, such as star roundness, and overall exposure length were less influential, only causing errors at extreme values. In optimal conditions without a tracking mount, this system was able to achieve an average of close to .01 magnitude error repeatably, an acceptable error for measuring many variable stars, and showing that inexpensive consumer equipment is capable of high-accuracy photometry.

Surface Engineering of Bioplastics

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Teacher: Sara Laux, University School, Chagrin Falls, OH
Mentor: Shixiong Zhu, Sr. Technology Manager, Geon Performance Solutions

Bioplastics have long been an area of interest, since they are more environmentally friendly than petrochemical-based plastics. Bioplastics can be more widely adopted if they can meet the performance requirements of various applications. One of such requirements is surface engineering, which this investigation explores. The question tested was "Is it possible to tailor the surface properties of biodegradable plastics?" The hypothesis predicted that it was possible to tailor the surface properties by adding hydrophilic or hydrophobic additives, which would make the bioplastics more hydrophilic or hydrophobic correspondingly. The materials used were corn starch, potato starch, rice starch, agar agar, paraffin wax, EBS wax, Polysorbate 80, water, glycerol, a weighing scale, a pot, a stove, chopsticks, an oven, petri dishes, a cup, a measuring cup, a dropper, an iPhone, and a hot press. The procedure used was to create samples of bioplastics from the corn, potato, agar, and rice starch, then press them with a hot press, then drop water on them, then measure the contact angle of their surfaces using an iPhone app. The measurement would be recorded. The hypothesis was supported. It was possible to tailor the surface properties of bioplastics and make them more hydrophilic and hydrophobic. Different bioplastics and additives render different surface properties. By tuning these properties, this can result in an expanded usage of bioplastics, as they will be able to meet the surface requirements of packaging, health care, automotive, and other industries, which in turn decreases pollution as bioplastics are environmentally friendly.

OREGON

Dynamic Extraocular Filtering: A Novel Method for Active Correction of Color Vision Deficiency, Validated with Steady-State Visual Evoked Potentials

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Color Vision Deficiency affects over 400 million people around the world, making it one of the most common genetic disabilities. There is currently no cure, prompting a need for an effective, non-invasive method to improve color contrast perception for Color Vision Deficient. In previous years, my research introduced a novel method of correcting contrast perception based on Differential Dynamic Illumination. While successful, this method had limitations, demanding the need for a more universal approach. This study proposes a novel correction method, based on actively controlling the wavelength spectrum that reaches the retinal photoreceptors. To verify the effectiveness of the proposed method, two phases of lab testing were conducted on a Color Vision Deficient subject with severe Deuteranopia. In the first phase, color contrast recognition rates were measured and calculated using randomized Standard Ishihara Test Plates. Results were analyzed using Fisher's Exact test. A statistically significant increase in color recognition was observed for modulation frequency of 15 Hz ($p=0.0104$), with a 100% recognition rate at frequencies 12 Hz or below ($p<0.0001$). In the second phase of testing, an EEG system was used to record Steady-State Visual Evoked Potentials (SSVEPs) from the Occipital Lobe in response to Red-Green chromatic stimuli with and without Dynamic Extraocular Filtering. Collected EEG spectra were analyzed to extract spectral density at stimulation frequency as a function of Red-Green balance in stimuli. Results confirm that the amplitude of SSVEP neural response increased with the application of Dynamic Extraocular Filtering, independently confirming increased color contrast perception.

OncoRx: An Integrative Approach to Identification of Pan-Cancer Molecular Biomarkers and Prediction of Targeted Multi-Drug Cancer Therapeutics

Darsh Mandera
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The current practice of treating cancer with radiation, chemotherapy, and immunotherapy is a one-size-fits-all approach, where patients with the same type and stage of cancer receive the same treatment. Research shows that this approach is ineffective 75% of the time. With microRNA (miRNA) having been identified as a key biomarker of cancer, precision therapeutics based on miRNA should provide the highest specificity and sensitivity by virtue of their cancer-specific expression and stability. However, identifying particular miRNAs that play a key role in driving cancer remains a challenge, as the expression of some types of miRNAs is found to be significantly different between normal and tumor tissues. The focus of this research is to create a pan-cancer solution using machine learning (ML) to identify key miRNAs as biomarkers of cancer and predict drug combinations based on miRNA. Data from 80% of cancer types from The Cancer Genome Atlas with 6,280 patients, 705 miRNAs, and 230 drugs was used. Top microRNAs were identified as key biomarkers using ExtraTreesClassifier, and were validated through KEGG pathway analysis and Gene Ontology enrichment analysis. Three ML models were implemented using multi-label algorithms: K-NearestNeighbors, AdaBoostClassifier, and OneVsRestClassifier. OneVsRestClassifier, an ensemble learning algorithm, yielded the highest accuracy. The final model was further tuned using cross-validation through GridSearchCV and K-Fold, and by using statistical techniques like F1 Score, Jaccard Score, and Accuracy Score. The resulting solution overcomes the challenges of monotherapy and allows oncologists to prescribe anti-cancer drug combinations with high accuracy based on patients' miRNAs, yielding higher survivability.

SAFE: A Sensor-Fusion Based Assessment and Prediction of Falling-Risk for the Elderly

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Every nineteen minutes an older adult dies from a fall, making falls the leading cause of injury death to that group. Cumulatively older adult falls cost upwards of $50 billion in medical costs annually and is anticipating seven fall deaths every hour by the year 2030. Programs (like STEADI) use walking and other mobility tests, visual inspection and surveys of past history of falls to assess for risks. However, the tests are ineffective in picking up changes in baseline risk for the aged population until the next 6 month routine visit. This work proposes a novel low-cost multi-sensor based solution 'SAFE', that uses IMU inertial sensors and camera input to predict the risk of falls quickly and accurately. IMU inertial sensor based devices are prototyped to collect 6-axis accelerometer data and capture video input to measure gait statistics with elderly subjects. A deep learning bi-directional LSTM network is fine-tuned and trained resulting in up to 94.26% accuracy. Using camera input and pose estimation models, gait speed is used to support the LSTM prediction. Results of the prediction with volunteer subjects shows up to 89.5% accuracy when predicting the likelihood of falling within six months for some participants. The derived gait speed metrics suggested an excellent correlation to the predicted results. SAFE accelerates sharing of fall prediction results allowing healthcare providers to assess the prediction in the risk of falling and take timely measures to prevent injury.

SOS.net: A Robust System Harnessing the Power of AI to Expedite Search and Rescue Missions

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According to the National Missing and Unidentified Persons System, over 600,000 people go missing around the US wilderness every year, and there are at least 1,600 people currently missing- these only being the ones that were officially reported. Current, drone-and-human-vision dependent systems in place are not only incredibly inefficient, but also tiresome for drone pilot operators, who carry out over 60 Search and Rescue (SAR) missions a year. Alternatively, thermal detection drones used are inaccurate and far too generalizing, picking up on unrelated, inanimate objects that radiate heat. This is where I saw Artificial Intelligence (AI), Machine Learning (ML), and their powerful Computer Vision (CV) capabilities coming into play. What is needed is a reliable system that can accurately locate and signal by recognizing visual indicators of human presence or distress, and AI's application is a crucial first step in being able to expedite SAR missions, relieving the strain on our SAR teams, and saving lives. The goal is to make human search missions much more refined and efficient by implementing RCNN's Resnet50 ML model methodologies. By open-sourcing SOS.net, meaning that all of the code, procedures, a snapshot of the trained model, and the option to access the entire dataset is available to the general public on Github to download and/or contribute towards its further improvement, enables SOS.net to be a dynamic, yet robust, AI system that has high potential for actual implementation and continued refinement as a tool.

Machine Learning-Guided Design of Novel Adeno-Associated Virus (AAV) Vectors for Human Gene Therapy

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Gene therapy has immense potential for treating conditions such as cancer, hemophilia, kidney disease, and inherited blindness by correcting defective genes directly. Adeno-associated viruses (AAV) are commonly used in gene therapy development and research due to their non-pathogenic nature in humans. A major bottleneck in designing safer and more efficient gene therapy treatments lies in creating novel viral vectors that exhibit reduced immune response or tissue specificity. Recent efforts have involved using machine learning to overcome this bottleneck by identifying novel viral vectors for gene therapy. Employing machine learning to screen out viral vectors that are predicted to be non-viable accelerates benchwork by reducing the number of mutant viruses that must be experimentally characterized for downstream application. In this project, we created a deep convolutional neural network (CNN) model that incorporates natural language processing (NLP) techniques to determine AAV capsid viability from its primary amino-acid sequence. Specifically, we created and trained a CNN model on the C1R2 dataset of complete single point-mutations plus random double mutations described in the paper "Deep diversification of an AAV capsid protein by machine learning" by Bryant *et al.* (2021). Our model achieved an accuracy of 0.7623 on the testing dataset of AAV mutants validated by Bryant *et al.* (2021), a 14.51% improvement over the CNN trained on the C1R2 dataset reported in Bryant *et al.* (2021). This project demonstrates proof-of-concept for successfully applying NLP to capsid engineering.

PENNSYLVANIA

Smart Club: A Sensing Device for Tracking Club Head Speed and Trajectory

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Golf is a sport that requires countless hours of practice and considers many different factors, including club speed and trajectory. Having a high club speed indicates that the ball will leave the ground at a high velocity and therefore travel further. In addition, the trajectory which the club travels is important as having the proper swing mechanism can improve the speed of the club dramatically. Therefore, it is imperative that a golfer have access to technology that can detect the club speed and trajectory of the ball in real time. Currently, there are commercial products that provide these, including the Trackman, but it is not portable and therefore cannot be brought onto the course. Therefore, there arose a need for a portable device that would provide the club speed and trajectory in real time. Through deriving an algorithm with the use of concepts such as relative motion and vectors and coding it into MATLAB, a program was devised to provide the club speed and then subsequently graph the 3-dimensional trajectory in real time, called the Smart Club. After preliminary testing, it was found that the results closely model the numbers given by commercial devices like the Trackman. Currently, testing is being continued to further shine light on the accuracy of the proof-of-concept design in comparison to the Trackman.

Controlling Vancomycin Resistant *Staphylococcus aureus* with Electroactive Bacterial Cellulose-Carbon Nanotube Bandages

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The opportunistic pathogen *Staphylococcus aureus* kills over 330,000 people every year and is becoming increasingly resistant to antibiotics, most recently vancomycin. In this study, bacterial cellulose-carbon nanotube (BC-CNT) bandages were engineered to eradicate vancomycin resistant *S. aureus. Komagataeibacter sucrofermentans* was cultured to produce a BC membrane at an air-media interface. Then, carboxyl-functionalized multiwalled carbon nanotubes (CNTs) were integrated into purified BC with surfactants, low-frequency sonication, and rotational incubation to create highly stable and electrically conductive BC-CNT bandages. Chronoamperometry was used to standardize the electric potential of the BC-CNT bandage, allowing low-level currents to flow between two terminal electrodes. Quantified fluorescent imaging of *S. aureus* after exposure to electroactive BC-CNT demonstrates that the bandage can inhibit S. aureus from forming biofilms. Areas of compromised *S. aureus* recovery around the working electrode (W.E.) also experience reductions in pH, which suggests that reactive oxygen species are generated as a killing mechanism. Bactericidal efficacy significantly improved when a concentration of vancomycin lower than the minimum inhibitory concentration (MIC) was added to the treatment, which suggests that electroactive BC-CNT resensitizes *S. aureus* to vancomycin. In this condition, the total biofilm area on the bandage was reduced by over 90% after a single hour of treatment. Scanning electron microscopy of *S. aureus* around the W.E. reveals a high degree of cellular stress following exposure to electroactive BC-CNT. This research presents a new direction for overcoming antibiotic resistant biofilm infections.

Predicting Lung, Heart, and Thoracic Cavity Volumes from Subject Demographics Using Machine Learning to Improve Lung Transplant

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Lung transplantation is the standard treatment for end-stage lung diseases. A crucial factor affecting its success is size matching between donor's lungs and recipient's thoracic space. Computed tomography (CT) scans can accurately determine recipient's lung size, but donor's lung size is often unknown due to the absence of medical images. This study aims to predict donor's lung, thoracic cavity, and heart volumes from only subject demographics to improve the accuracy of size matching. A cohort of 4,610 subjects with chest CT scans and basic demographics, including age, gender, height, weight, race, smoking status, and smoking history, was used. The right and left lungs, thoracic cavity, and heart depicted on chest CT scans were automatically segmented using developed U-Net models, and their volumes were computed. Eight machine learning models were developed to predict the volume measures from subject demographics and validated using the 10-fold cross-validation method. The developed models showed promising performance in predicting thoracic cavity volume, right and left lung volume, total lung volume, and heart volume with R^2 ranging from 0.430 to 0.628, mean average error (MAE) ranging from 0.075 to 0.736 liters, and mean average percentage error (MAPE) ranging from 10.9% to 15.2%. Our results demonstrate the feasibility of using subject demographics to predict lung, heart, and thoracic cavity volumes. The developed tool may be used to facilitate lung size matching for lung transplant and ultimately improve post-transplant survival.

Predicting Postoperative Lung Cancer Recurrence and Survival Using Cox Proportional Hazards Regression and Machine Learning

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Surgical resection remains the optimal treatment for early-stage lung cancer. However, the recurrence rate after surgery is unacceptably high (30%-50%). Despite the significant efforts, it remains elusive to accurately predict the likelihood and timing of recurrence. In this study, we propose to predict postoperative lung cancer recurrence by identifying novel image biomarkers from preoperative chest CT scans. A cohort of 309 patients was selected from 512 non-small cell lung cancer patients who underwent lung resection. We used Cox proportional hazard regression analysis to identify risk factors associated with lung cancer recurrence and compared its performance with machine learning (ML) methods in predicting lung cancer recurrence. The goal is to improve our ability to predict the risk and time of a seemingly "cured" cancer to come back and facilitate personalized surveillance strategies and thus minimize lung cancer recurrence. Our experimental results showed that surgical procedure, TNM staging, lymph node involvement, body composition, and tumor characteristics are important determinants of the risk of both local/regional and distant recurrence for recurrence-free survival (RFS) and overall survival (OS). ML-based approaches and Cox models exhibited similar performance with an area under the receiver operative characteristic (ROC) curve (AUC) ranging from 0.75-0.77. ML-based approaches may be a useful analytic approach for survival prediction in lung cancer recurrence. We expect that this computer tool could be an important addition to the clinical practice of lung cancer treatment and may improve decision-making for patients, oncologists, and surgeons, ultimately improving the long-term quality of life for patients.

PHILADELPHIA AND DELAWARE

Using qPCR to Quantify the Presence of CART T Cells in vivo

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Multiple sclerosis is a disorder in which the immune system attacks the protective covering of the nerve cells in the central nervous system (CNS). B cells may contribute to disease progression. Therapies that deplete CNS-resident B cells is a potential treatment for MS. Recent clinical studies have shown that decreasing peripheral B lymphocytes in MS patients reduces disease progression. However, these methods may not efficiently eradicate B cells in the CNS. CAR T cells are a new, potent cancer therapy that also target B cells. To efficiently deplete CNS B cells, we tested CAR T cells in a mouse model of MS. However, we saw no difference in the disease in mice treated with or without CAR T cells. To determine why we didn't see a benefit, we developed an assay to test whether the CAR T cells stuck around (engrafted) or not. We validated a qPCR assay first using CAR plasmids and then with blood spiked with CAR T cells. Using this validated qPCR assay on blood samples from the MS study, we found that there was no difference in signal between the non-CAR T cell and CAR T cell treated groups. Based on the blood results so far, we were unable to detect CAR T cells in the MS samples. Therefore, this may indicate that the CAR T cells did not engraft, explaining the lack of effect on MS.

Modeling Freshwater Microplastics and the Effects of Anthropogenic & Watershed Factors Using Machine Learning

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Microplastics are a contaminant with significant potential for harm as they are associated with adsorbed heavy metal toxicity, persistent organic pollutants, and harmful pathogens. With plastic production continuing to rise and the need for policy and mitigation efforts, modeling has become an important tool. Past research on modeling microplastics explores transport dynamics, whereas this study uses anthropogenic and watershed factors to predict freshwater microplastics via machine learning. The study was executed in the Delaware River Basin with 115 samples from 36 sites. 500mL of each sample was filtered and microplastics visually identified. The average microplastic concentration per 500mL was 5.0 ± 3.5. Microplastic data was also normalized by discharge and upstream watershed area to calculate the transport of microplastics load per day per km^2, with an average value of 17.7 ± 64.7. Then, data on watershed and anthropogenic factors was compared spatially to each sampling site. This found statistically significant ($p < .05$) relationships between microplastics per day and Strahler stream order ($R = -.34$), slope ($R = .52$), and number of upstream wastewater treatment plants ($R = .43$). Microplastics per 500mL had statistically significant correlations with days since January 1 ($R = .46$) and discharge ($R = -.22$). Three models were then created (linear, gradient boosting, random forest), and both the machine learning models outperformed the linear model, with the random forest predicting microplastic transport per day having an $R = .73$. This study shows that machine learning is a viable method for using anthropogenic and watershed characteristics to model microplastics.

Predictive Analysis of Invasive Plants

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Invasion by non-native plants costs the US over $21 billion annually and can cause devastating effects on whole ecosystems. The best strategy of solving this problem efficiently and cost-effectively is through early detection and eradication, which relies on the accurate prediction of invading species. However, studies in this area are extremely limited. Hence, this study aims to utilize Machine Learning (ML) to develop a novel method of predicting the spread of invasive plants at an early stage. Using three Machine Learning algorithms: Random Forest (RF), Multivariate Multiple Linear Regression (MMLR), and Support Vector Machines (SVM), the desired models can be created. Trained on an invasive plant dataset from Africa and California, and correlated with environmental data from the Visual Crossing, the models produced proved highly accurate and reproducible in their ability to identify and predict the distribution patterns of the most invasive plants and the regions most at risk from invasion. When the methods applied on the national Tamarisk genus, the results were comparable to the Terra and Aqua satellite vegetation data from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors. Additionally, these models acted as a novel way of creating plant specific invasion curves, allowing greater knowledge of how to minimize and manage the spread of these invasive plants. These methods and models, applicable to any other taxa and location, represents an unparalleled opportunity to implement timely and proactive management strategies against biological invasions.

Year Two: siRNA-Based Gene Silencing in the Extracellular Matrix of Abdominal Aortic Aneurysms with Simulation Modeling

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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, and reversing disease pathophysiology is difficult as cells are unable to regenerate new elastic fibers. Year one of experimentation served as a proof of concept to verify the feasibility of this technique and the use of siRNA to stimulate elastic matrix assembly.

This year's research expands to investigate 16 genes, with the objective to determine the impacts of EGFR silencing in aneurysmal aortic smooth muscle cells (EaRASMC), and observe potential unintended consequences of the technique, with a goal to stimulate the regeneration of elastic matrix and inhibit proteolytic enzymes. It was hypothesized that siRNA sequences that inhibit the EGFR gene can therapeutically reverse matrix aberrations associated with AAAs to regenerate & restore healthy elastic matrix and slow/reverse AAA growth. siRNA effects on MMP expression levels & elastic fiber assembly were studied in in vitro cultures of EaRASMC from simulated rat models. Relative gene expression was determined with qPCR. Improved elastic matrix regeneration was achieved through decreases in MMPS & increases in elastic matrix production. This research demonstrates how siRNA-based gene silencing to augment elastogenesis may be used as a treatment for AAAs.

CAPCODRE: A Computational Systems Biology and Machine Learning-Based Approach to Predict Cognitive Disorder Risk in the Elderly

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As global life expectancy improves, the population of the elderly, persons that are aged 65 years and older, is steadily increasing as well. However, with aging populations a greater prevalence of cognitive impairment has emerged, ranging from mild dementia to severe dementia such as Alzheimer's disease due to genetic and environmental influences, among others. The purpose of this research was to develop a computational algorithm to predict the risk of developing cognitive disorders using a dual machine learning and systems biology approach. The proposed method CAPCODRE (Computational Approach to Predict Cognitive Disorder Risk for the Elderly) utilized air, water, and noise pollution data coupled with a gene-protein interaction network, in addition to cognitive impairment hospitalizations in the United States to create a tailorable, interactive network able to predict risk of dementia and Alzheimer's disease. This network was inputted into a random selection optimization algorithm that selected optimal training parameters for training via KNN, random forest regression, and decision trees. CAPCODRE was successfully able to predict and model risk of cognitive health issues through measures of specificity, sensitivity, and accuracy of >90%. The algorithm was integrated into an app for users to receive personalized predictions based on their medical history and geographic location. CAPCODRE can point to the extent of the effect of environmental pollution on human health and reveal steps to mitigate risk of severe cognitive impairment. This research also has the potential to address racial disparities in cognitive disorder diagnoses and treatment, promoting more equitable and accessible care.

Statistical Assessment of TESS Demographics and Prospect Earth-Twins Via Habitability Constraints in Python

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Supervising Mentor: Nicholas Lauersdorf

Considering the increasing amounts of planetary data available, this investigation aimed to automate the process of identifying likely habitable exoplanet candidates within big datasets-based on planetary radii, ESI, and HZ location. The researcher developed a computational model in Python to digest TESS data, survey selected because of short orbital period candidates suitable for atmospheric characterization. The model-was proven to be successful for (1) mining prospective rocky exoplanets within the HZ, (2) analyzing demographic tendencies-throughout filtering stages, and (3) incorporating post-processing visualization. TESS data tends towards those candidates likely incapable of harboring water due to bias in detection method by instrument sensitivity. The researcher hypothesized that likely habitable exoplanets share constant qualities that may influence radii, stellar flux, and HZ. Large-exoplanets tend to be detected orbiting around K, G, F, A-stars, while Earth-twins and Super-Earth's are detected orbiting M, K, G stars. Luminosity and stellar flux within the HZ remain within constant ranges of .004-4.441 and .213-1.758, respectively. These values coincide with the luminosity and stellar flux ranges of M, K, G stars, spectral types hosting majority of exoplanets which survived all constraints, thus supporting my hypothesis. The-researcher created a TESS Habitable Exoplanet Catalog (THEC) to narrow the candidates for spectroscopy and follow-up confirmation. A THEC candidate was referred to the list of ACWG priorities of the TESS Follow-Up Program (TFOP).

Sustainable Aviation: Fuel Use Reduction Through Algorithmic Routing in Airspace

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Globally, commercial aviation generates one billion tons of CO2 emissions annually. Fuel consumption is >30% of the airline budget. While current practices automate the complex handoffs from a safety perspective, they assume static inputs and ideal conditions and rely on human decisions at ATC to solve for congestion. Further, prevailing practices retain the historically reductionist approach to nodes available for route planning. Our work relies on the ubiquity of inexpensive compute to expand the node space available for route planning, both ahead of filing a flight plan, and in real-time, considering airspace congestion, winds aloft, time, and aircraft weight and altitude-based fuel burn curves as inputs and solving for minimal fuel use through a modified 4-D Dijkstra implementation. The model was trained on data from N=2,819 commercial flights and resulted in savings of 426 kg on average per flight on a test of n=96 routes over the United States mainland. The results translated into a reduction of between 5.3% and 6.9% in fuel spend per flight with approximately one-sixth of it realized from optimizing descent. As a robotic, ultra-low-cost module, this can surface inflight re-routing options that clear a threshold of fuel or time savings. At scale, it delivers direct carbon offsets and meaningful reductions in climate liability for commercial aviation.

Creating an Aerodynamic Control Recovery Systems for Coupe Body Cars to Increase the Probability of Regaining Control at High Speeds

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Speed is a factor considered at the time of an accident, as only a 1% increase in speed increases the probability of fatal accidents by 4%. Can the creation of a Non-Electronic Aerodynamic Control Recovery System and an Active Safety Electronic System in coupe cars increase the likelihood of regaining control at high speeds?

If when creating the systems, "flaps" are integrated into coupe body cars and these produce pressure and wind resistance, then this technology will reduce the speed of the car quickly and prevent the tires from rising from the ground increasing the probability of regaining control at high speeds. An RC was used, which was modified by placing 3 "flaps" and electronics (in the case of the second system). To test it 3 subjects performed a maneuver. For this, the car was placed accelerating and passing through the left of a cone, then turning sharply to the right and then another sharp turn to the left. It was repeated 5 times and 5 times in reverse with each car and with each subject using the wind in 2 different directions. The Electronic Experimental Auto was the most effective surpassing by 0.75m (46.44%) and 1.53sec (48.80%) on average to Auto Control. The Non-Electronic Experimental Auto regained control 0.39m (21.73%) and 0.04sec (1.03%) before Auto Control. The hypothesis was accepted since the Experimental Cars regained control in less time and distance than Auto Control.

The Influence of the Mental Health of Puerto Rican Teenagers Student-Athletes on Their Physical Performance

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In Puerto Rico, there is not much research on the mental health of teenage student-athletes. However, various types of research found that many students in the country suffer from different mental disorders. Mental health affects how they think and act; at the same time, mental health has numerous physical effects that influence physical performance. This research focuses on how mental health affects the physical performance of a teenage student-athlete in Puerto Rico. It uses a questionnaire of 52 questions to collect non-probabilistic information about the mental health of student-athletes that participated and their physical performance. It found that mental health indirectly affects the physical performance of these teenage student-athletes. If a student-athlete has poor mental health, their physical performance will reduce. Many students consider that they have good mental health but suffer from anxiety, little motivation, and sadness, among other feelings that lower quality sleep and, on occasion, cause eating disorders. By not sleeping or eating well, the body suffers from fatigue, muscular pain, physical tiredness, and agitation, where their physical performance is going to be affected; a teenage student-athlete with poor mental health is not going to produce at his highest potential. This information should give more significant importance to the mental health of these student-athletes and help them achieve their full potential.

Resilience of Advanced Polymer - Glass Fiber Composites

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Physical properties of thermoplastic polymers can be improved with the incorporation of glass fibers into polymeric products, which significantly improves physical properties such as tensile strength, stiffness and dimensional stability at higher temperatures.

This paper investigates optimization methods for improving resilience of advanced composite structural items made of polymers with the inclusion of glass fibers and specially formulated reinforcement elements. Tested variables included a) thickness and amount of glass fibers dispersed within the polymer matrix, b) addition and placement of woven mesh elements on open flat surfaces of a polymer panel and c) addition and selective placement of tension setters on ridges, which are the most likely areas of external stress. Ridged polymer test panels were tested for flexural strength using variable loads (ASTM D790 standard).

Tension setters were found to be best embedded in laterally-extending rib elements of the composite structure, preferably as end-portions of rib elements. Open mesh woven elements should be placed strategically within the polymeric body to provide impact strength where needed the most. These innovative optimized structural

designs showed higher strength (up to 330% improvement vs. the base polymer panel) and higher impact resistance (up to 550% improvement), while also reducing weight by 15-21%, as compared to conventional non-reinforced polymer panels (at the same structural strength). These novel results opened a viable path to a new range of high-performance niche polymer composites. The results contributed significantly to a recently filed US utility patent application.

SOUTH CAROLINA

The Phytoremediation of *Escherichia coli* in Contaminated Water by *Lemna minor, Salvinia minima*, and *Azolla caroliniana*

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Pathogenic strains of *Escherichia coli* can cause potentially fatal diseases like hemorrhagic colitis. Phytoremediation is the process in which plants remove contaminants like *E. coli* from the environment. *Lemna minor, Salvinia minima*, and *Azolla caroliniana* are three aquatic plant species that have been tested in previous phytoremediation research, but their abilities to expunge *E. coli* from water have not been directly compared. The purpose of this study was to test and compare the abilities of *L. minor, S. minima*, and *A. caroliniana* to reduce *E. coli* concentration in contaminated water. It was hypothesized that aquatic plants would decrease the concentration of *E. coli* in water due to the antimicrobial flavonoids they produce, and *L. minor* would kill more bacteria than *S. minima* and *A. caroliniana* because of its fast growth rate and extensive roots. Plants were placed in fertilizer solution, and *E. coli* was added to each sample. Initial and final concentrations (CFU/mL) of *E. coli* in the samples were determined after a serial dilution. *L. minor, S. minima*, and *A. caroliniana* resulted in 97.890%, 90.292%, and 99.063% decreases in *E. coli* concentration, respectively. A Kruskal-Wallis test found that results were statistically significant, $H(3) = 51.413$, $p < .001$, and Dunn's pairwise tests found significant differences between *L. minor* vs. control, *S. minima* vs. control, and *A. caroliniana* vs. control. The results of the present study suggest that *L. minor*, *S. minima*, and *A. caroliniana* are equally effective at remediating *E. coli*-contaminated water.

Becoming a Scientist: A VR Simulation Making Research More Accessible

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Mentor: David Renton

With a national teaching shortage restricting students' passions and expensive research equipment limiting science curriculums, it is vital that accessible alternative forms of laboratory educational experiences are made available to students. I have created a research VR simulation to provide an alternative learning experience that in its final form, students can choose microbiology, biochemistry, or molecular biology labs to perform. Through the diverse amount of labs offered in the simulation, students can perform realistic lab procedures while cleaning their lab station in the process. When creating the project, with pinpoint detail, I painstakingly crafted virtual lab materials that closely replicated real-life equipment. Next, I built mountains of code connecting the player's real-life movements to the virtual lab. Each arm, each hand, and each finger required seemingly endless functions so that the player could perform realistic lab objectives. After presenting my project in a school contest, I won first place and an investor in the community wanted to fund my project. I am currently working with Lablight AR, a company that builds software tools to connect with AR, to expand its outreach beyond my state. Yet, in my community, I am reaching out to schools and libraries to potentially implement it into their programs. Each conversation is another step closer to reaching my goal of using my VR program to help others in their educational pursuits.

The Modification of Jury Instructions to Improve Juror Verdicts and Confession Recognitions in a Criminal Trial

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False confessions are a leading cause of wrongful convictions in the American legal system. Jury instructions have been identified as an effective judicial safeguard in an effort to prevent wrongful convictions and allow jurors to better comprehend confession evidence in the courtroom. The purpose of this study was to determine whether the modification of standard jury instructions would have an effect on juror verdicts, confession identifications, and overall juror decision-making. It was hypothesized that participants given modified jury instructions would have the highest correct verdict determinations and confession recognitions with both the coerced and voluntary trial transcripts. Participants were recruited through Amazon Mechanical Turk, and they were randomly assigned into an experimental group. Participants read a trial transcript and completed a questionnaire. Descriptive statistics were calculated, and logistic regression tests determined statistical significance. The use of modified instructions displayed a statistically significant effect on both verdict determinations and confession identifications, Wald χ^2 (4, N=180) =6.786, $p<0.05$ and Wald χ^2 (4, N=180) =6.749, $p<0.05$, respectively. The interaction effects between modified instructions and the coerced confession transcript were also shown to be statistically significant. The results demonstrated that participants who were given modified jury instructions had the highest percentages of correct verdict determinations and confession recognitions compared to participants who were given standard instructions or no instructions. Participants given modified instructions were also more aware of factors such as interrogation coercion. Further research should be conducted to maximize the potential of jury instructions and other safeguards in a criminal trial.

Microplastics from Mats: The Creation of Microplastics in the Environment

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Previous research has suggested that abiotic factors, such as UV irradiation, facilitate the degradation of artificial polymers, such as polyethylene, into microplastics. However, current research has yet to explore how varying abiotic factors impact the degradation of polyethylene foam from a water mat, recreational mats that are frequently seen and used on bodies of water, including Lake Murray, SC. Microplastics can be vectors for organic and inorganic pollutants and substances, which means they can have detrimental effects on human, animal, and ecosystem health. These tiny pollutants can have a major impact due to their widespread nature, which is why it is important to understand the manner in which they are created. In order to test the impact of abiotic factors on the degradation of the water mat, an experimental method was employed. 12 treatment groups and 6 control groups were tested. Experimental treatments consisted of UV irradiation and thermal radiation from 2 separate lamps. 6 samples of polyethylene were exposed to different conditions under each lamp. These environmental conditions consisted of lake water, pure water, and no water with two samples: one subjected to mechanical abrasion and the other without mechanical abrasion. The amount of microplastics was collected from each sample every two weeks. The individual samples were then manually counted using a handheld tally counter in order to quantify the dependent variable. Multiple ANOVA tests were conducted, however, only one that analyzed the groupings of light treatment with consideration for mechanical abrasion produced a significant p-value (p=0.006) conveying.

Object Recognition with Contextual Reasoning Based Fuzzy Neural Networks for the Uncertainty Output

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Object recognition is an important task in image processing and fuzzy neural network (FNN) is a popular tool for object recognition. However, when applied to datasets that present complex and fuzzy features, the accuracy of such FNN is degraded, and their uncertainty of output is increased. To tackle this problem, we propose in this paper a contextual reasoning based fuzzy neural network. The proposed method, called CR-FNN, is composed of two phases. In the first phase, the CR-FNN algorithm is a classifier for object recognition, which outputs the predicted value of the FNN. In the second phase, the categories of images are used as the basis for context comparisons. We embed the network output with a local search strategy to determine the object category by the features ranking and the distance between the contextual knowledge and the object. The performance of the developed algorithm has been evaluated on three datasets. The datasets both present the characteristics of complex and fuzzy image features. Further analysis is made with parameter metrics such as accuracy (ACC), Hamming loss (HL), average precision (AP), weighted accuracy (WA), recall, and Area under the ROC Curve (AUC). The proposed FNN with contextual reasoning has better performance over the traditional FNN and existing baseline algorithms. The experimental results show that the accuracies of CR-FNN are 19.8%, 9.8%, and 11.2% higher than the traditional FNN on the three datasets respectively and provide a new solution to the uncertainty of the output of FNNs.

SOUTHWEST

An Integrated Approach for Immediate and Long-Term Air Quality Regulation and Monitoring in Mexico

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Air pollution is among the leading causes of premature deaths across the world and disproportionately impacts the Global South due to lesser air quality regulation and research on regional air pollution monitoring when compared to the United States, Europe, and East Asia. This project consists of three models to address air quality in different ways in Mexico. The first program includes data cleanup, visualization, training, and testing for a machine-learning model to provide hourly air pollution forecasts up to 48 hours in advance as an immediate means of minimizing the harm of hazardous air pollution events for numerous cities, with high seasonal accuracy scores up to $R^2 = 0.77$. Second, physical model simulations validated by a statistical analysis of historical relationships between ozone and its precursors present long-term policy suggestions to safely reduce ozone levels at each city, a challenge due to ozone's counter-intuitive behavior (highlighted during the pandemic lockdowns). Finally, to provide continuous estimates of air pollution in regions without monitoring stations, a machine-learning model that incorporates historical ground monitoring, meteorological parameters, and physical model simulations is developed and tested, with cross-validated R^2 scores up to 0.78 - the first of its kind covering all of Mexico.

Deep Learning Prediction and In-Vitro Validation Of Novel Anti-Cancer Peptides from Marine Taxa Database

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Anti-cancer peptides (ACPs), a class of small peptide molecules, have gained increasing attention in cancer research due to their ability to target and kill cancer cells selectively, sparing normal cells. ACPs, unlike chemotherapy, have less toxicity and fewer side effects, are highly specific to cancer cells, are easy to synthesize and modify, and are cost-effective therapeutics. Unfortunately, the experimental identification of novel ACPs is time-consuming and expensive, therefore computational methods to identify key features of ACPs is promising.

Here, a robust deep-learning model was developed that recognized molecular features of MCF-7 breast-cancer ACPs from the CancerPPD database. Next, 20,000 peptide entries from marine taxa catalogued in the J. Craig Venter Institute PhyloDB database were screened for potentially novel ACPs by the Deep learning model. After 3-fold cross-validation, the model showed a sensitivity and specificity of 95% and an accuracy of 98% in predicting known ACPs in the CancerPPD database. After learning features of previously validated MCF-7 ACPs, the model selected top 40 novel ACPs in the PhyloDB database with >90% ACP probability. MCF-7 Breast Cancer Cell culture validation of the top 4 novel ACPs shows that the ACPs exhibit a statically significant cytotoxic effect on cancer cells at concentrations above 10-100 □g/ml. In summary, for the first time, the deep learning approach described here applies learned information on ACPs to make new predictions in an unknown dataset and would present the first AI (artificial intelligence) predicted novel ACPs with *in vitro* validation.

A Novel Under-Sink Engineered Device to Detect Acidic Chemicals to Convert to Biodiesel

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Many chemicals are present in cleaning, pharmaceutical and personal care products found in school settings, farming, manufacturing and industry businesses which can end up washed down the sink drain and into water bodies where they may impact the environment. This study engineered a novel sink drainage prototype using Arduino/UNO/R3 code for a pH probe/motorized ball valve to communicate when chemicals are poured down the drain, diverting 80% or more of the acidic fluid volumes into a holding tank ≥ 95% of the time. Using an acidic chemical like cooked vegetable oil (pH = 5.3), green chemistry was used to process it to biodiesel with an 85% or better quality test rating. Twenty trials of the basic/acidic mixtures were tested against the prototype coding function and four modifications made to the working prototype. The results of the final prototype tests suggest that on average the pH probe identified the pH of the liquids with more precise range than pH paper, the motorized ball valve was signaled to close/open 100% each time, and 81.66% of the acidic liquid volume was routed to a holding tank. The biodiesel averaged a 99.97% purity rating for methanol and an average of 0% precipitate fallout after 72 hours for biodiesel conversion testing. Today, the adequate supply of uncontaminated groundwater and water coming from wastewater going back into surface/ground water is crucial for the health of our NM families, but also for the growth of agriculture production and cutting-edge industry in New Mexico and across the globe.

Implementing Quantum-Classical Machine Learning Architectures to Optimize Convolutional Neural Networks

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Larger sets of data and information in computational systems are oftentimes misinterpreted or tedious to analyze because of human error. Classical machine learning (ML) can be sufficient in categorizing data, but as dimensionality and features increase, it becomes more difficult to find patterns and relationships in the data. By implementing quantum computing, the performance of ML can improve performance, scalability, and enable the solution of problems that are currently intractable for classical computers.

This research studies the effects of quantum-classical machine learning architectures on convolutional neural networks (CNNs). I created a total of 4 different Quantum-Classical CNNs. The first consisted of a parametrized quantum circuit that worked via the implementation of a single qubit y-rotational value. The second worked via a four-qubit y-rotational value, the third through entanglement, and the fourth via the quantum approximation optimization algorithm. Each circuit was run 3 times under 5,10, 15, and 20 training iterations (epochs) and with 100, 150, and 200 samples each to find the average result in accuracy in data predictions.

The accuracy of test data performance improved as each algorithm had an increasing amount of training iterations as well as when there were more data samples to learn from. Not only did accuracy improve, but the behavior of each model improved with the implementation of quantum protocols by quickly processing the data and having high accuracy in predictions. Overall, by combining classical and quantum computing in machine learning, quantum algorithms have the ability to perform faster calculations.

Utilizing the Learned Latent Structure from Dimensionality Reduction Algorithms to Prevent the Effects of Catastrophic Forgetting in Neural Networks

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In recent years, the neural network has become one of the most powerful tools in the field of machine learning. However, while neural networks are extremely good at learning a singular task, they struggle when being trained on more than one.

In my research, I attempt to overcome this problem by automatically separating the different tasks which a machine learning model is required to learn. My solution takes advantage of the different appearance of samples across tasks, which can be automatically quantified using dimensionality reduction algorithms, such as PCA (Principal Component Analysis). By using these algorithms to separate a dataset based on its content, we can approximate a separation of each task that needs to be learned. In order to test the effectiveness of this approach, I tested this novel algorithm's ability to learn to identify handwritten Arabic numerals, in both their western and Persian forms. Compared to simply training a single neural network on the combined dataset, the novel approach was only able to achieve a 0.58% increase in accuracy and was able to split the dataset into separate tasks with 95.68% accuracy.

Through my experimentation, I was unable to find a practically useful improvement in accuracy with the novel algorithm. However, the performance increase which was achieved, along with the high accuracy of the task separation, shows some promise in the tested algorithm. Through improvements to the process by which tasks are separated, it's possible that a more significant performance increase could be achieved.

TENNESSEE

The Cytotoxic Effect of Silver Nanoparticles on Human Lung Cells

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The recent influx of innovation in the nanotechnology industry has drastically increased the concentration of airborne nanoparticles in the air, with silver nanoparticles (AgNPs) making up approximately a quarter (~$2.5 bn.) of the industry. It is estimated that about 14% of inventoried silver nanotechnology products (e.g., silver-embedded textiles, household appliances, biomedical devices) could potentially aerosolize AgNPs during usage. Additionally, AgNPs have been shown to penetrate deeply into the alveolar region, but their effects on this region are not well studied. In this experiment, it was hypothesized that AgNPs would cause cellular cytotoxicity based on a literature search.

A549 human alveolar epithelial lung cells were exposed to concentrations of 60 nm AgNPs between 0 and 2.5 µg/mL. Cell counts, a trypan blue viability assay, and photomicrographs were taken every 24 hours over a 72-hour period. The results indicated a significant decrease in the cell population ($F(5, 24) = 3.508$; $p = 0.0160$) and viability ($F(5,24) = 6.953$; $p = 0.0004$), supporting the hypothesis about AgNPs' cytotoxic nature.

The morphological effects suggested cell death (intracellular vacuoles) and possible inflammation at higher concentrations (>1.5 μg/mL). These results indicate that inhaled AgNPs may pose a serious health hazard to the human lungs because they damage the one-cell thick epithelial layer of the lungs. Long-term effects may include an increased risk of lung cancer, asthma, and COPD. Future research should test longer exposure periods and confirm the presence of inflammation by testing for pro-inflammatory cytokines.

Using Deep Neural Networks to Identify Exoplanets

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In 2018, NASA initiated the Transiting Exoplanet Survey Satellite (TESS) to search for planets outside of our solar system. TESS has been gathering large sets of star light data, but the quantity of data is too large for scientists to analyze. Recently, machine learning has been applied to the TESS star light data sets. One example is the Nigraha Pipeline, an open-source convolutional neural network which is designed to identify unknown exoplanets from the light of stars. The complexity of the Nigraha Pipeline requires a large training data set and long run times. This work will utilize Deep Feed Forward (DFF) Neural Networks to identify potential exoplanets using a smaller training data set and maintaining high accuracy. Multiple DFF networks were created using varying number of hidden layers and activation functions. Using only one-third of the training data used in the Nigraha Pipeline, accuracies approaching 90% were achieved as compared to 88% for the Nigraha Pipeline. In addition, a significant decrease in computation time was observed with the DFF network taking minutes as compared to the Nigraha Pipeline taking hours. This achievement will allow for more exoplanet data to be accurately classified and progression for a deeper understanding of surrounding solar systems.

Towards Personalized Medicine: Using Machine Learning to Predict Immunotherapy Effectiveness on Heterogenous Tumors *in silico*

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Personalized medicine has the potential to revolutionize patient care using targeted therapeutics. Within the field of personalized medicine, simulation of tissue-scale biological systems has shown great potential in analyzing the effects of therapeutics. PhysiCell, an open-source agent-based modeling simulation platform, has the capability to model interactions of immune and cancer cells. However, PhysiCell simulations are time-consuming due to the millions of interacting cells. Machine learning presents a promising solution to predict the efficacy of a cancer treatment without running a PhysiCell simulation. Using PhysiCell, a training data set composed of 2000 immunosurveillance simulations was created with various parameters values. The simulations were run with two separate tumor morphologies based on histopathological images of pancreatic adenocarcinoma. Training data was used to create both a random forest classifier and a random forest regressor for each morphology. These trees predict the fraction of dead cancer cells based on parameter values and rank the parameter importance in predicting the fraction of dead cancer cells. The classifier predicted the fraction of dead cancer cells with accuracies of 70.91% and 84.55% for Morphologies One and Two, respectively. The regressor predicted the fraction of dead cancer cells with accuracies of 69.39% and 84.55% for Morphologies One and Two, respectively. The parameter importance rankings for regression and classification showed similarities within each morphology, while the parameters of importance varied between the two morphologies. Also, the regressor generates a prediction in under 10 seconds for a parameter set, while a PhysiCell simulation can take up to 40 minutes.

Understanding the Spatiotemporal Variability of Wildfires and its Correlation with Climatic Factors in the United States

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The intensity, duration, and frequency of wildfires has consistently increased across the US over the past few decades, which has had long-term implications for human health, infrastructure, and the environment. In 2020, more than 10 million acres of land burned, making it one of the deadliest years in recent times. The objective of this research was to understand the spatiotemporal patterns and variability of wildfire occurrences and its correlation with climatic factors across the US. The location and date of fires from 1984-2021 were used to explore trends in wildfire occurrence across different ecoregions in the US. In addition, various climatic variables across these ecoregions were analyzed, and their correlation with burned area and frequency of fire occurrence were examined. Ecoregions with the largest burned areas and greatest number of fires showed significantly increasing trends for both over the years. In addition, increasing trends were observed for temperature and vapor pressure deficit (VPD), while decreasing trends were observed for relative humidity and drought index in the ecoregions with the maximum fire occurrences. Strong significant positive correlations between burned area and both temperature and VPD were observed across most of the ecoregions, while a negative correlation was observed with relative humidity. Results from this study implicates climate as a dominant driver of changing fire activity in the US. Better understanding of the variability in fire occurrence and patterns and their correlation with climatic factors will help in planning for effective fire management.

Understanding 8D Music Perception Using Mobile EEG

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Listening to music has been found to have large impacts on the brain, especially for those with ADHD. Music can even decrease the amount of slow, or low frequency, wave activity in the brains of those with ADHD (Chew, 2010). ADHD is a sensory disorder commonly associated with inattention, hyperactivity, and impulsiveness that affects many individuals. Sensory disorders have been treated using music therapy. This study brought in the aspect of 8D audio, which is when music pans and sounds like it is moving. If 8D audio can change the brain waves measured on an EEG, then it could possibly be used to help in music therapy as well. Because researchers were not allowed to know if participants had ADHD, a procrastination scale was used as a substitute for supplementary research to begin to know how those with ADHD would react to the audio. Participants listened to songs in 8D audio and with normal music, then did a procrastination scale and answered about how they felt while listening to the music. 8D audio was found to significantly decrease the levels of alpha waves compared to when individuals were listening to normal music, meaning that it most likely stimulates the brain more. The participants who responded positively to the audio in general had higher scores on the procrastination scale. These results imply that 8D would be a successful tool in music therapy for its stimulating.

Agro-Rhizoremediation Rhizoremediation with Agro-transformed *Oryza sativa* to Facilitate Arsenic Degradation in-situ

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Mentor: Amanda Dunn

The World Health Organization reports that arsenic contamination of soil and water is considered a global issue, threatening the health of over 150 million people worldwide. Arsenic accumulation in *Oryza sativa* (rice), in particular, is becoming increasingly problematic because of the repeated use of arsenic-laden groundwater for rice cultivation. The Environmental Protection Agency has set a limit of fewer than 20 parts per million (ppm) for arsenic in soil and less than 0.01 ppm in drinking water. However, current solutions to remediate arsenic are expensive and ineffective. Rhizoremediation is a promising technique to detoxify soil arsenic in situ, but it is not 100% effective, and arsenic still escapes into the edible parts of the plant. Therefore, in addition to remediating arsenic from the soil, it is vital to prevent arsenic accumulation in the rice grain. Therefore, this project aims to develop a joint procedure using rhizoremediation along with transgenic rice plants that have been genetically transformed with arsenic-resistant genes to facilitate self-detoxification. Raw sequences of 16s rRNA from 82 soil samples obtained from the National Center for Biotechnology Information were processed through Qiime2 to examine bacterial taxonomy in arsenic-contaminated and uncontaminated soil rhizospheres. *Pseudomonas* and *Burkholderia* genera constituted over 63% of the microbial community in the contaminated rhizospheres. *Agrobacterium tumefaciens* was transformed with acr3 and arsC arsenic resistance and reduction genes, respectively. Transformed *A. tumefaciens* was used to infect wounded rice cotyledons, which were then cultivated in plant tissue culture media to develop transgenic rice plants.

Finding an Accessible, Environmentally Friendly Solution to Water Purification: Testing *Aloidendron barberae* and *Bambusa dolichomerithalla* as Natural Coagulants on Copper Ion Concentration Using UV-vis Spectrophotometry

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As a result of Cu-based agrochemicals and industrialization, the concentration of Cu^{2+} in aquatic circulation is predicted to increase by more than 50% by 2100, leading to detrimental impacts on the health of both terrestrial and marine organisms. However, current methods of heavy metal pollution treatment are restricted to chemical coagulation, or the use of iron and aluminum salts to adsorb ions to their surfaces; problematically, the salts used are environmentally toxic, perform at an inconsistent rate, and adversely impact disadvantaged populations. In contrast, natural coagulation relies on the same adsorption processes but uses naturally occurring biomass to remove contaminants.

Therefore, it was hypothesized that natural coagulation through the independent variables of *Aloidendron barberae* and activated charcoal *Bambusa dolichomerithalla* held potential as naturally-occuring, beneficial alternatives to chemical salts through four parameters: improved accessibility, environmental friendliness, consistency, and reduction efficacy of heavy metal concentration. Thus, the dependent variable was molar concentration of Cu^{2+}. To quantify results, spectrophotometry and the Beer-Lambert law were applied in which the molar concentration of a Cu^{2+} sample was calculated from absorption of light as defined by a calibration curve specific to Cu^{2+}. Different masses of both independent variables were tested in 5.0 mL 0.033M $CuSO_4$ for two hours, within which a standardized procedure of testing samples via transferring a small volume into a clean, dry cuvette at thirty-minute intervals with a spectrophotometer was followed. To replicate real-world water treatment conditions, the jar testing method recommended by the American Water Works Association was used for the total.

Traffic Counting System Using Machine Vision

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Accurate vehicle counts on roadways are important for traffic departments and transportation agencies for transit planning, road maintenance, lane expansion, traffic alerts, and traffic light control. Prevalent methods such as pneumatic tubes, inductive coils, piezoelectric strips, and optical beams are disruptive, non-concurrent, inaccurate, and temporary. A statistically based machine intelligence approach using video cameras capturing traffic, that is highly accurate and autonomous, is developed. The computationally efficient process is nearly real-time and can be realized on an edge device co-located with the camera. The crux of the algorithm involves identifying a vehicle presence indicating a statistical signature in fixed partitioned areas in each of the lanes. The lane-wise traffic counts are incremented when the statistical metric in the partitioned areas exceeds certain dynamic thresholds. When applied to traffic video captures from vantage points above roadways under various lighting conditions, an overall traffic count accuracy of 96%, that is comparable to, or better than the published state-of-the-art performance, was achieved when counting about 2500 vehicles. The same algorithm and thresholding formula was used for different roadways. This method does not rely on horsepower-intensive and unnecessarily complicated image segmentation, machine learning-based vehicle identification, and motion tracking steps. Moreover, it can be mapped to software implementation on edge-computing embedded platforms, centralized traffic operation centers, or the cloud, enabling widespread deployment to cover the entire roadway network accurately, concurrently, continuously, autonomously, and economically.

The Salt to my Pepper: The Effects of Utilizing the Bioactive Descriptors of Piperoyl Piperidine (Piperine) on B16-F10 as a Neoteric Treatment for Melanoma

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Melanoma occurs from melanocytes, which produces the pigment cells. Piperine with the application as an ingredient in black pepper, is used in traditional medicine, justified by studies on its biological effects as antioxidant, antitumor, and drug availability-enhancing characteristics potential. The purpose of this study was to examine inhibitory effects of piperine on B16-F10 cell growth to view the ability to decrease cell proliferation. It was hypothesized that piperine would inhibit B16-F10 growth, and higher concentration would result in higher tumor inhibition. T-1 delineated 0.1 uM of piperine, T-2 delineated 0.2 uM, and T-3 delineated 0.3 uM. After 24 hours, the control had an increase in tumor volume by 1025%, T-3, with the most concentration, demonstrated a TGI of 70.23%. T-2 undergoing a 60.96% TGI and T-1 undergoing a 41.63% TGI. Cell proliferation levels dropped dramatically, no matter the cell density, killing B16-F10 growth. Future research includes testing greater amounts of piperine, testing cancers with similar cell function, such as basal and squamous cell, and tests on human cells. Understanding piperine having an inhibitory effect on melanoma, we can accumulate extensive knowledge about the processes involved with cancer onset and growth. From there, we are one step closer to a cure.

A Low-Cost Low-Power Long-Range Location Tracking System Using Helium Network

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Mentor: Gary Xu

Every 40 seconds, a child is reported missing in the United States. In addition, about 10 million pets are lost every year. There is a strong need for location tracking devices. However, most tracking devices are short-range, expensive, and have low battery life, such as those using GPS technology and cellular services. Users of these

devices often need to charge the battery once every few days. In this paper we present a low-cost low-power long-range location tracking solution using the public Helium network. Helium is a worldwide decentralized wireless Internet of Things (IoT) network consisting of "hotspots." Devices can communicate with hotspots via the LoRaWAN (Long Range Wide Area Network) protocol. A sensor sends beacon signals periodically to the nearby hotspots, and an RSS (Received Signal Strength) based algorithm is used to triangulate the sensor from these hotspots. A prototype tracking device with location tracking software using cloud computing was created. Field tests were done by collecting 10146 data points in geographically diverse locations across the US. From preliminary analysis, the median distance between the hotspots and the sensor's true location is 750 meters. This proves that the LoRaWAN network can reach long ranges. Maximum likelihood and least square location estimate algorithms were developed and tested. Using the maximum likelihood method, we were able to calculate the locations of 2016 points with a median error of 442 meters. The estimated cost of the final product is around $30, with battery life of over a year on a coin battery.

VIRGINIA

Engineered Opto-Active Polymeric Systems for Protease Detection

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Mentor: Dr. Jerald Dumas, Hampton University

The detection of proteolytic activity in vitro is a promising field in understanding and identifying biological processes that occur within living cells. There is little research and experimentation on how to incorporate fluorophores within a polymer system that will allow for the detection of chemical reactions dynamically, hindering the understanding of biological processes in time-specific areas. Opto-active casts are formulated from the incorporation of DQ-gelatin (dyed-quenched gelatin) in a polyurethane (PUR) network. The DQ-gelatin will be conjugated into the network, allowing the polyurethane to act as a cast, 'holding' the protein in place for Trypsin (metabolic enzyme) to degrade the DQ-gelatin. When the fluorescein isothiocyanate (FITC) fluorophores in the DQ-gelatin are cleaved by Trypsin, the released fluorophores produce a measurable fluorescent emission that can be read via a plate reader. The issue lies in whether this system can be created to view cellular processes in real-time through the controlled environment of the polymer network. Fluorescent polymers, specifically polyurethane, are a promising platform for the real-time detection of protease activity due to their biocompatibility, controllable mechanical properties, and low reactivity with biological molecules. Through an ANOVA test, it was shown that there is a significant difference in the fractional difference between groups with and without Trypsin. This acts as a preliminary study to be expanded to other intrinsic fluorophores using proteases important in the regulation and detection of cancer, specifically MMP-9 activity, to be acted as a biosensor for biological cues in metabolic pathways.

FASFA: A Solver for the Fuzzy Differential Equations

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This paper introduces fast adaptive stochastic function accelerators (FASFA) for gradient-based optimization of stochastic objective functions. It works using Nesterov-enhanced first and second moment estimates. The method is simple and effective during implementation because of its intuitive/familiar hyperparameterization. The training dynamics can be progressive or conservative depending on the decay rate sum. It works well with low learning rates and mini batch sizes. Experiments and statistics showed convincing evidence that FASFA could be an ideal candidate for optimizing stochastic objective functions, particularly those generated by multilayer perceptrons with convolution and dropout layers. In addition, the convergence properties and regret bound are some of the bests on online convex optimization framework. Future experiments could modify FASFA using bandit-based multi-start strategy.

The Effect of a Luteolin Supplement on Blue Light-Induced Cellular Senescence in White-Eyed Drosophila melanogaster Models of Age-Related Macular Degeneration

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The leading cause of visual impairment is age-related macular degeneration (AMD), an irreversible eye disorder that causes permanent blindness and has a 40% increased mortality risk. AMD is projected to rise from 196 million to 288 million cases worldwide by 2040. Blue light exposure leads to oxidative stress in the retina, causing retinal pigment epithelium (RPE) cells to undergo cellular senescence (when cells stop dividing but do not die). The accumulation of senescent RPE cells leads to inflammation and retinal damage, ultimately resulting in AMD. Luteolin is an antioxidant, anti-inflammatory agent, and a senolytic (a substance that clears senescent cells). The purpose and novelty of this research is to ascertain Luteolin's effect on blue-light induced AMD *in vivo*, through white-eyed *Drosophila melanogaster* models of AMD. Flies were exposed to blue light to induce AMD, measured through a phototaxis assay. Flies with AMD would not exhibit a natural tendency to move towards light; therefore a "pass" would be considered flies in the light vial. The results validate the phototaxis assay, since pass rates were significantly higher (p-value of 0.0049) for healthy flies (69.88% mean) than for AMD flies (20.99% mean). The hypothesis—Luteolin supplementation would suppress AMD—is supported since pass rates were significantly higher (p-value of 0.0009148) for AMD flies fed Luteolin (48.53% mean) than for AMD flies on standard diets (20.99% mean). Considering the limited, ineffective treatments currently available, senolytics could be effective, low-cost treatments for all stages of AMD.

The Effect of Dispensing Mechanism on Drop Precision

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Glaucoma is a group of diseases that lead to structural optic neuropathy and functional deficiency in vision. Worldwide, 80 million people have glaucoma with a blindness rate of 12%. There is no cure for glaucoma, but it can be managed effectively with disciplined use of daily eyedrops. However, eye drops are difficult to administer correctly due to shaky hands, incorrect amount of force applied, and applications of medicine on the eyelids or eyelash. Therefore, a more precise way of administering this medicine topically could help many people treat eye diseases. This study compared the difference between two experimental groups of piezoelectrical crystals and compressed air to see how precise they were compared to the control group of administering by hand.

Prototypes for each of the three experimental groups were created using a combination of 3-D printing, eye dropper bottles, and the appropriate experimental material. These prototypes were tested by creating 25 drops of four different volumes (25 μL, 40 μL, 55 μL, and 70 μL). The percent error was calculated for each of these tests. The mean and standard deviation were calculated as the measure of central tendency and spread, respectively. A t-test was performed to determine the significance at the 0.05 level. Both tests of the experimental group versus the control were statistically significant rejecting the null hypothesis that the control and experimental group had an equal mean in favor of the alternative hypothesis.

Future work for this study includes a cost-benefit analysis of materials and testing more mechanisms.

Investigating the Selectivity of Thymoquinone Towards Cancerous Prostate Cells

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Androgen insensitivity in PC-3, a variant of prostate cancer, has been recognized as highly lethal and drug-resistant due to its reduced dependency on substances that are commonly inhibited through modern treatments, such as androgen. As a result, there is a lack of effective treatment options. However, thymoquinone, a substance commonly known for its role in essential oils and readily available, has risen in popularity as a potential treatment option due to its implied anticancer effect from previous studies. Additionally, our previous study demonstrated that thymoquinone lowers PC-3 viability. Despite the implied anticancer effect, whether thymoquinone selectively targets PC-3 only remains largely unstudied. The purpose of this study is to investigate the selectivity of thymoquinone and compare the effects of thymoquinone on PC-3 (cancerous cells) and HPrEC (noncancerous cells) viability. In this study, a monoculture model and a co-culture mode were used. After utilizing an Acid Phosphatase Assay for cell viability, both the cancerous cell monoculture and co-culture model data support the notion that thymoquinone inhibits cancer cell viability, which is consistent with our previous study. However, when comparing the cancerous well plates with the noncancerous cells that were grown in a co-culture setting, the data clearly shows that the noncancerous cell viability values with thymoquinone added were not lower than the control. Early data suggests that thymoquinone selectively targets cancerous cells, revealing thymoquinone as a potential treatment option. Future research should investigate the efficacy of thymoquinone application further.

VIRTUAL

The Exploration of Machine Learning for Morphological Neuron Classification in the Neocortex

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This study discusses the applications of machine learning techniques to classify neurons based on their morphological features. By utilizing these models, neurons can be accurately identified and categorized based on their shape and structure. The study outlines the various deep-learning models used in this classification process, specifically using a supervised artificial neural network. The use of deep learning models allows for more efficient and effective research, as they can analyze large amounts of data faster and more accurately than traditional methods. This improved methodology has the potential to accelerate the development of targeted and novel therapies for a variety of neurological and neurodegenerative diseases, such as Alzheimer's and Huntington's. The data showed the optimal artificial neural network had 2 hidden layers, consisting of 64 and 64 nodes respectively, with a learning rate of 0.001 and momentum of 0.9. The model produced an MAE of 3.08, RMSE of 1.76, R-Squared value of 0.899, and overall accuracy of 96.10% in classifying neurons over 100 successive trials. With this ability to predict and classify neurons, the neural network proves the viability of machine learning in broader applications within the field of neurodegenerative diseases.

RevealED: Uncovering Pro-Eating Disorder Content on Twitter Using Deep Learning

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The Covid-19 pandemic induced a vast increase in adolescents diagnosed with eating disorders and hospitalized due to eating disorders. This immense growth stemmed partially from the stress of the pandemic but also from increased exposure to content that promotes eating disorders via social media, which, within the last decade, has become plagued by pro-eating disorder content. This study aimed to create a deep learning model capable of determining whether a given social media post promotes eating disorders based solely on image data. Tweets from hashtags that have been documented to promote eating disorders along with Tweets from unrelated hashtags were collected. After prepossessing, these images were labeled as either pro-eating disorder or not based on which Twitter hashtag they were scraped from. Several deep-learning models were trained on the scraped dataset and were evaluated based on their accuracy, F1 score, precision, and recall. Ultimately, the Vision Transformer model was determined to be the most accurate, attaining an F1 score of 0.877 and an accuracy of 86.7% on the test set. The model, which was applied to unlabeled Twitter image data scraped from "#selfie", uncovered seasonal fluctuations in the relative abundance of pro-eating disorder content, which reached its peak in the summertime. These fluctuations correspond not only to the seasons, but also to stressors, such as the Covid-19 pandemic. Moreover, the Twitter image data indicated that the relative amount of pro-eating disorder content has been steadily rising over the last five years and is likely to continue increasing in the future.

Isolation of Health-Benefiting Bacteria from Probiotic Foods

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Probiotic Foods are known to have many health benefits such as bolstering intestinal health, reducing risk to many diseases, and reducing antibiotic resistance, to name a few. Because these foods have so many benefits, I hypothesized that by isolating bacteria from them, these health benefits could be extended to all kinds of different foods.

The bacteria of interest were isolated from Great Value Greek Plain Nonfat Yogurt by using MRS medium to encourage the growth of lactic acid bacteria. After several strains had been isolated, they were used to ferment orange juice and carrot juice for about three days. By using HPLC (High-Performance Liquid Chromatography), several differences between the original juices and the fermented juices were found. E. Coli Bacteria were tested against antibiotics as well as salt concentrations after being exposed to one of two treatments: fermented juice and non-fermented juice.

Through this experiment, I have been able to observe positive results from three bacterial strains. I was able to observe a decrease in antibiotic resistance to ampicillin, hygromycin, carbenicillin, and kanamycin when I exposed E. Coli bacteria to juices fermented by my isolated bacteria.

Constructing a Novel Multidirectional Machine Learning-Based Stochastic Process Model to Simulate the Latitude of the North Atlantic Jet Stream

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The North Atlantic Jet Stream (NAJS) is greatly influential in the distribution of precipitation and the development of severe weather events, such as cyclones, tropical storms, and hurricanes, throughout North America and Europe. Significant shifts in the latitude of the NAJS can have disastrous impacts on human and environmental well-being. However, current climate models' simulations of jet stream latitudes are inaccurate due to their reliance on simplified physical parameterizations. Similarly, unidirectional machine learning models lack complexity and do not consider the interconnectedness of the physical drivers of the NAJS. In this study, a set of multidirectional stochastic process models were created to simulate the latitude of the NAJS by applying the machine-learning technique of vector autoregression to times series constructed from a suite of global climate models. Statistical and time series analyses, including cointegration tests and lag selection, were used to determine parameters for the stochastic process models. To determine the optimal model, the root mean square error (RMSE) of each model was calculated with respect to historical, observational data from the ERA5 global reanalysis. The optimal model was created from MPI-ESM-1-2-HAM data, and its RMSE score demonstrated a significant 36.1% improvement from the RMSE score of the baseline, unidirectional model. These results show that multidirectional models exhibit considerably greater reliability in forecasting changes in jet stream latitudes than traditional unidirectional models. Forecasts from this novel, highly accurate stochastic process model can be applied to forecast future latitudes of the NAJS and facilitate preparation for upcoming catastrophes.

Application of Deep Learning Models into the Prediction of Interleukin-6 and -8 Cytokines in Sickle Cell Anemia Patients

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Interleukin-6 (IL-6) and Interleukin-8 (IL-8) are cytokines related to general immune function, but within Sickle Cell Anemia (SCA) patients, their overproduction tends to cause autoimmune reactions. These vital cytokines engage in the pathophysiology of SCA, but the extent to which they're associated with the disease's genetics needs further exploration. This research paper seeks to further the study of IL-6 and IL-8 in SCA patients and the possibilities of predicting their presence in patients based on Haptoglobin alleles and various other hematological factors using artificial neural networks and deep learning techniques. This was done through a cross-sectional study of 60 sickle cell anemia patients and 74 healthy individuals who provided the basis of this study's data. The data was used to build a machine learning model that would predict levels of the IL-6 and IL-8 cytokines. The deep learning model found a non-linear correlation between the Haptoglobin alleles and the production of IL-6 and IL-8, predicting their over levels in patients with an accuracy of 90.9% and r-squared value of 0.88 based on the given inputs. The machine learning models built in this paper have the potential to accelerate the development of targeted treatments and diagnoses to those suffering from Sickle Cell Anemia and its specific immune complications.

WASHINGTON

The Effects of Limiting Citrate-Derived Acetyl-CoA Synthesis on the Development of Exhaustion in $CD8^+$ T Cells

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T cell exhaustion is a hypofunctional fate observed in cancer that causes loss of full mitochondrial function. Preventing T cell exhaustion could sustain the immune system's anti-tumor response. An accumulation of lipid droplets in exhausted T cells has been observed, raising the question of how lipid synthesis might be related to the progression of T cells towards exhaustion. I investigated the impact of limiting intracellular Acetyl-CoA production on the development of T cell exhaustion by targeting ATP-citrate lyase (ACLY), which converts citrate to Acetyl-CoA. $CD8^+$ T cells from C57Bl/6 mice were activated for 24 hours through the TCR in vitro. Cells either received no additional stimulation (acute stimulation - AS) or continuous TCR stimulation for 6 days (chronic stimulation - CS). Within each AS/CS group, cells were treated with ACLY inhibitor concentrations of 0μM, 10μM, 20μM, or 40μM per subgroup. Cells were analyzed by flow cytometry for markers of exhaustion. In both AS and CS conditions, a greater number of cytokines were produced by cells treated with 40μM ACLYi than cells treated with lower concentrations. CS cells were most impacted: 5.39% of cells without ACLYi were $IFN\gamma^{hi}$ $TNF\text{-}\alpha^{hi}$, compared to 51.0% with 40μM ACLYi. No notable difference in PD-1 or TIM-3 expression was observed in any cell group. These data suggest that ACLY inhibition preserves T cell effector function under chronic stimulation conditions. The optimal dosage of ACLYi may lie around 30μM. Future steps include repeat testing under hypoxia and in vivo experimentation with mice tumors.

Optimizing Word2Vec

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From the video game Semantle to ChatGPT, Natural Language Processing (NLP) systems, such as GloVe (Global Vectors for Word Representation) and Word2Vec (transforming Words to Vectors) are necessary in communicating with humans, as well as answering questions and classifying texts. Previous research has used these systems to predict genomes or stocks. The wide array of applications provided motivation for research into reducing the runtime and memory usage of GloVe by reducing the dataset size through dimensionality reduction techniques. I investigated how using Principal Component Analysis could reduce the dimensions of GloVe, and tested the preservation of data in the vector dataset by using the Birch Clustering algorithm to find semantically similar words. I determined that almost all data was stored in half the number of dimensions, with even smaller reductions. I also identified bias in the GloVe words database stemming from the training dataset from viewing the data on lower dimensions.

Analysis of Ring Galaxies Detected Using Deep Learning with Real and Simulated Data

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Understanding the formation and evolution of ring galaxies, galaxies with an atypical ring-like structure, will improve understanding of black holes and galaxy dynamics as a whole. Current catalogs of rings are extremely limited: manual analysis takes months to accumulate an appreciable sample of rings and existing computational methods are vastly limited in terms of accuracy and detection rate. Without a sizeable sample of rings, further research into their properties is severely restricted. This project investigates the usage of a convolutional neural network (CNN) to identify rings from unclassified samples of galaxies. A CNN was trained on a sample of 100,000 simulated galaxies, transfer learned to a sample of real galaxies and applied to a previously unclassified dataset to generate a catalog of rings which was then manually verified. Data augmentation with a generative adversarial network (GAN) to simulate images of galaxies was also used. A catalog of 1151 rings was extracted with 7.4 times the precision and 15.4 times the detection rate of conventional algorithms. The properties of these galaxies were then estimated from their photometry and com-pared to the Galaxy Zoo 2 catalog of rings. With upcoming surveys such as the Vera Rubin Observatory Legacy Survey of Space and Time obtaining images of billions of galaxies, similar models could be crucial in classifying large populations of rings to better understand the peculiar mechanisms by which they form and evolve.

Biomimicry of Boxfish: A Computational Analysis and Wind Tunnel Study of the Aerodynamic Drag Reduction of Class 8 Heavy Vehicle Trailers

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In August 2021, the Environmental Protection Agency (EPA), through its Clean Truck Plan, proposed new standards to promote clean air and reduce pollution from heavy-duty vehicles starting in model year 2027. One of the recommended approaches is for heavy-duty vehicles to improve fuel economy by 40% by the year 2027.

Class 8 trucks achieve fuel economy in the range of 6-8 miles per gallon of diesel. At speeds of 70 mph, 65% of the energy is spent in overcoming aerodynamic drag (McCallen et al., 1999), making aero-drag the largest opportunity for improving efficiency. A truck consists of a cab in front and a trailer in the back. Cab aerodynamics is well understood and modeled as is evident with the near-airplane-looking cabs on the roads with aero hoods, aerodynamic bumpers, streamlined mirrors, and roof extenders. The trailer has remained as cubical containers that are designed more for stacking and storage than being aerodynamic.

Inspired by the Boxfish hydrodynamics, different add-on shapes were used in CFD simulations to provide a streamlined shape to the trailer and its corresponding drag measured. A 3D-printed model of the cab and trailer with add-on attachments was tested in a wind tunnel to validate the simulation. When comparing the bio-inspired to a standard trailer, a drag reduction of 13.8% in computational and 16.7% in the wind tunnel experiments was achieved. These results translate to 14%-16% efficiency gains of Class-8 trailers by bio-mimicking the Boxfish.

WEST VIRGINIA

Reach Into the Mind: A Study of the Human Brain and its Application to Brain-Computer Interface

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Teacher: Lisa Berry

In our project, we wanted to test if we could control modern-day technology using an EEG headset. The purpose of our project is to see if we can improve and revolutionize mind-controlled technology. To test our mind-controlled technology we paired a Neurosky mind wave mobile two headset, to our robotic arm. We powered our prototype using stepper motors and for our present design, we used Nema-23 motors. We used our minds to control the robotic arm, and we would be able to move it in any direction we desire. The Neurosky headset has three different aspects. We utilized all of them to be able to control our arms. Our science fair project has two main phases which allow us to improve upon our research on BCI (Brain computer interface) technology. The first phase is the creation of our prototype and to see if we can connect our EEG headset to our arm. So far in phase two, we have built a much-improved design, then our prototype. Soon, we will test our new headset on different people, and we want to see how brain waves differ from person to person. We plan to use this research, to implement it into an A.I database that can improve upon the reliability, consistency, and accuracy of BCI technology. The goal is to have a seamless arm that can be used by a variety of people including surgeons, engineers, and the average person.

Ophidia Vision: Inside the Terrarium Lab

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“Ophidia Vision: Inside the Terrarium Lab” is an experiment that used machine learning to detect a reptile’s identity. The scientific question is: *Can a facial recognition machine learning model be modified and trained to detect a reptile’s (ball python) identity?* Using machine learning and cameras is less invasive to animals than other current ways of animal identification. The purpose of the experiment was to convert an existing machine learning model for face recognition of humans into a model to recognize a baby ball python snake. Koch, Zemel, & Salakhutdinov (2015) included the main data source used to lay the foundation for implementing a new type of model for a reptile. The experiment included photography, coding, python language platforms, model training, and analyzing the results. A library called OpenCV (computer vision) was a source I added to this experiment to program a laptop’s webcam as my camera. The original snake images (the dependent variable) and modified images were used to create my new facial recognition model for the ball python. I used a Convolutional Siamese Neural Network (CSNN) to train my model to learn the bodies of reptiles and its one-shot model to analyze the collection of images in a sequence (92% high achieved accuracy model). Colab imported an image dataset to train an image classifier on it and to evaluate a model using a few lines of code. The hypothesis was: 70% of the time, the precision rate of the model will be greater than 0.5 on a scale of 0 to 1. The data supported my hypothesis, and the precision rate during the experiment was 100. I believe this experiment was a step toward creating safer engineering practices for snakes. I also felt like a social justice worker and an engineer.

Powering Our House with Water: Testing a Water Turbine

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Have you ever wondered how the flowing of water can be turned into electricity? Normally, water and electricity cannot go together, so you would think it is not possible. However, with the help of a turbine and a generator, the kinetic energy in water can be converted into mechanical energy, and then turned into electrical energy, or electricity. There is a growing demand for energy, with a specific interest in portable power sources. To develop a portable unit and to test on this process, a miniature model of a turbine was constructed. Then, water was poured onto it (flow rate) at different speeds maintaining a constant elevation from where the water was poured (water head). The number of rotations per minute (rpm) of the turbine shaft that yielded mechanical power output were counted, which was later experimentally observed with three standard turbine-generator units. It was experimentally observed that if the flow rate is increased, shaft rotations as mechanical power, and, generator output as electrical power will also be increased. To verify this experiment, three standard sets of turbines, and generators were tested using supply water line and measuring electric output using a multimeter. Thus, by using the turbine-generator units under tap water and measuring voltage and current (electric output) using the multimeter, the results from the previous experiment were verified. This project is the first step towards building a portable hydropower turbine.

Consequences of a *dot-1.1* Deletion on Germ Cell Components in *Caenorhabditis Elegans*

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The evolutionarily conserved DOT1 family of proteins is essential for development in higher mammals. However, overactive DOT1L acts as an oncoprotein, most notably in childhood leukemia. Although deleting DOT1 genes leads to excessive cell death, down-regulation may be a promising treatment if potential negative impacts and apoptosis can be avoided. Consequently, our study focused on the outcomes of a DOT1 gene knockout and on the molecular components that cause DOT1 gene deletion lethality. Using *Caenorhabditis elegans (C. elegans)* as a convenient system, we bred a nematode strain with a *dot-1.1* deletion in concert with a *ced-3* mutation to minimize the typical side effects of a *dot-1.1* knockout. We hypothesized that (1) a *dot-1.1* deletion would impact the P granule morphology and localization due to the similar consequences that occur with a *dot-1.1* deletion and P granule function inhibition, and (2) *dot-1.1* deletion lethality is linked to irregular pgl-1 expression because faulty gene expression can lead to embryonic lethality and *dot-1.1* and *pgl-1* have similar characteristics. In this study, we found no change in P granule structure in mutants. However, we discovered that the *dot-1.1* deletion occasionally caused P granules expression in a third cell in embryos and larvae along with the two expected germ cells, indicating an additional cell with germline potential. Furthermore, we found no significant difference in levels of PGL-1::GFP expression after *dot-1.1* was deleted, suggesting that *pgl-1* expression functions properly in a background without *dot-1.1* and therefore is not the cause of embryo death in *dot-1.1* mutants.

Yellow to Green: An Unsupervised Machine Learning Approach to Bus Stop Redistribution

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The transportation sector is the largest source of greenhouse gas emissions, making up 29% of US emissions, with school buses being a significant contributor. Last year, this study aimed to lower carbon emissions at a local high school by rearranging stops within existing routes using the Google Maps API. This year's study builds upon previous work by validating the optimization results with statistical tests and extending the optimization to other schools. To further optimize the bus system, bus stop consolidation was considered to reduce the total number of buses, particularly, as bus driver shortages continue to worsen across the nation.

This study also presents a new approach to bus route optimization by reducing the number of routes through bus stop recombination with an unsupervised machine learning approach– the k-means algorithm. Testing the k-means algorithm on the initial 30 routes indicated that the process worked best on smaller, more centralized areas. So, k-means was applied to two smaller areas each with 7 routes to regroup the stops while removing a bus. This reduced the travel distance by 22% and 12% for the two areas. Overall, the optimization would save 9.6% in total route distance and a calculated $15,198 on fuel each year (at a fuel cost of $4.50/gallon). The optimization would be able to prevent 35 metric tons from being emitted into the atmosphere each year. To further improve efficiency, other clustering algorithms can be explored such as graph-based clustering, density-based clustering, and fuzzy k-means clustering.

WISCONSIN/UPPER PENINSULA MICHIGAN

Novel Lipopeptide-Like Antibiotics from *Xenorhabdus Szentirmaii*

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Antimicrobial resistance (AMR) is one of the top 10 global public health threats. To combat this global health threat, it requires new antimicrobial drugs from new natural sources. The bacterial genus *Xenorhabdus* is a new resource for the discovery of novel antibiotics. The antimicrobial compounds of *Xenorhabdus* species are primarily produced by non-ribosomal peptide synthetases (NRPS) and polyketide synthetase (PKS) genes. Here, we focus our studies on *Xenorhabdus szentirmaii*, which produces many antimicrobial compounds effective against a variety of microbial species including animal, and fungal pathogens. We showed that *X. szentirmaii* primarily produced more potent antimicrobial compounds during the stationary phase. We also showed that production of antimicrobial compounds depended on the function of phosphopantetheinyl transferase (PPTase) encoded by the gene *ngrA*. From a large-scale genome analysis, we showed that *X. szentirmaii* contains 17 NRPS/PKS genes. We also separated the antimicrobial compounds into methanol and dimethyl sulfoxide (DMSO) fractions. The liquid chromatography-mass spectrometric (LC-MS) of the methanol fraction showed that it contains a wide range of low-to-high-abundance compounds (e.g., peptides, amino acids, lipids, nucleotides, etc.) with a molecular weight ranging from 50 to 2,000 Da. The antimicrobial compounds in DMSO are heat stable and are likely a mixture of lipopeptides that attenuate the pathogenic antibiotic-resistant microorganisms. Collectively, our studies identified novel lipopeptide-like antibiotics from *Xenorhabdus szentirmaii*.

Transcriptomic profiles of NK-cell populations in Hepatocellular Carcinoma (HCC)

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Natural Killer (NK) cells -both circulating (cNK) and liver resident (lr-NK) - are a major component of innate host defense against HCC. NK cell dysfunction is associated with the development and progression of HCC. Through single cell RNA sequencing analysis, we aimed to analyze the gene expression profiles (GEP) of NK cell populations in four patients (pts) with HCC based on their location in the liver. We isolated and compared NK cell transcriptomes among samples from specific sites in the liver: tumor core - TC, tumor periphery -TP, and adjacent normal liver - NL. Seven NK cell clusters were identified through analysis, reflecting differences in phenotype and maturity. The GEP of NK cells in TC and TP were similar, but distinct compared to those from NL. NK cells in TC and TP were predominantly lr-NK cells and mature cNK cells compared to NL, which was composed of lr-NK cells and adaptive-like NK cells. Differential expression of genes regulating key immunomodulatory pathways were noted between lr-NK cells in TC vs. NL and TP vs. NL. The functional significance of differences in GEP noted between NK cells in TC and TP compared to NL needs further exploration to unlock their therapeutic potential.

Impact of Social/Traditional Media on Political Polarization

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There is a common perception that political polarization is increasing in American society and the blame is often assigned to highly partisan traditional media (e.g., TV news channels) and the emergence of social media echo chambers as the major influencers of political opinion. In this paper, we examine the impact of traditional and social media on political polarization in society via simulations. These simulations examine what happens when a population with normally distributed unipolar political views is exposed to social/traditional media espousing very different types of political views. Our simulations reveal that the political polarization in a population is deeply affected by the political views espoused in the media. If the media is primarily unipolar in terms of political views, the population ultimately become politically unipolar as well. On the other hand, if the media is politically bipolar, the population ultimately becomes politically bipolar. Interestingly, the simulations reveal that social media echo chambers can undo the polarizing impact of partisan traditional media if the echo chambers strictly show content matching the current political views of the users. However, if social media echo chambers expose the users to extreme political views, a population that is initially unipolar in political views will ultimately look like two different populations with very different political centers.

An Accurate Super-Resolution Approach for Low-Field MRIU Imaging via U-Net Network

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Low-field (LF) MRI scanners have power to revolutionize medical imaging by providing portable and cheaper alternative to high-field MRI scanners. However, such scanners are usually significantly noisier and lower quality than their high-field counterparts. This prevents them from appealing to global markets. The aim of this paper is to improve the SNR and overall image quality of low-field MRI scans (called super-resolution) to improve diagnostic capability and, as a result, make it more accessible. To address this issue, we propose a Nested U-Net neural network architecture super-resolution algorithm that outperforms previously suggested super-resolution deep learning methods with an average PSNR of 78.83 ± 0.01 and SSIM of 0.9551 ± 0.01. Our ANOVA paired t-test and Post-Hoc Tukey test demonstrate significance with a p-value < 0.0001 and no other network demonstrating significance higher than 0.1. We tested our network on artificial noisy downsampled synthetic data from 1500 T1 weighted MRI images through the dataset called the T1-mix. Four board-certified radiologists scored 25 images (100 image ratings total) on the Likert scale (1-5) assessing overall image quality, anatomical structure, and diagnostic confidence across our architecture and other published works (SR DenseNet, Generator Block, SRCNN, etc.). Our algorithm outperformed all other works with the highest MOS, 4.4 ± 0.3. We also introduce a new type of loss function called natural log mean squared error (NLMSE), outperforming MSE, MAE, and MSLE on this specific SR task. Additionally, we ran inference on actual Hyperfine scan images with successful qualitative results using a Generator RRDB block.

TaxHorn: A Novel, Taxonomy-Aware, Beta-Diversity Metric for Comparison of Microbiome Populations

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

While there are numerous metrics currently available for measuring beta diversity, none of these are

particularly optimized for work within the human microbiome. I set out to create a new distance metric, optimized for the microbiome with respect to taxonomy. To determine what would be required of such a tool, I first tested four existing metrics (*Bray-Curtis*, *Horn-Morisita*, *Euclidean*, and *Unifrac*) against a microbiome dataset containing samples of microbial populations from several individuals of varying degrees of health. I generated every possible pairwise combination of these samples, to which the distance metrics were then applied to. The information gained from this showed me what areas needed to be improved, and where I should begin. Of all of the metrics, the *Horn-Morisita* index proved most useful. I then designed a custom metric, which calculates said index to each taxonomic level of every sample. Finally, I applied a weighted mean to merge the seven remaining diversities into a single value for each sample with less focus on the immense variety of species. This metric, *taxHorn*, allows one to accurately estimate the degree to which two microbiome samples are different. This could potentially be used to detect the beginning of bacterial infections within immunocompromised individuals so that they can be medicated before an infection can fully develop and to further our understanding of the microbiome as a whole.

WYOMING AND COLORADO

Pharmacophore Analysis Driven Deep Neural Networks to Discover Novel Anticancer Drug Combinations

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Mentor: Prof. Daniel LaBarbera, Colorado University Anschutz Center for Drug Discovery

Drug combination therapies have shown effective performance in treating cancer through increased efficacy and circumvention of drug resistance through drug synergy. Two avenues can be used to discover drug combinations: a novel approach that utilizes natural products in the form of Traditional Chinese Medicine (TCM) herbs compared with the textbook approach of utilizing existing chemotherapy drug combinations. TCM herbs achieve efficacy due to synergistic interactions between the active ingredients. Therefore, the pharmacophore relationships in herbal compounds which synergize can potentially be applied to chemotherapy drugs to drive combination discovery. Machine learning approaches have been developed to identify drug combinations, especially deep neural networks (DNN), which have achieved state-of-the-art performance in many drug discovery tasks. Here, we developed a drug protein interaction (DPI) prediction DNN, DeepDPI, to employ DPI drug representations and achieved state-of-the-art performance. Two DNNs were also developed to predict novel drug combinations: DeepTCM, which predicts combinations in herbs, and DeepCombo, which predicts synergy in chemotherapy drugs. We used an ensemble architecture enhanced with a novel similarity-based weight adjustment (SBWA) approach and both models accurately predicted drug combinations for both known and unknown drugs. Lastly, a screening was conducted using each model where DeepTCM predicted combinations where drugs had similar targets, while DeepCombo predicted combinations where one agent potentiated the other, with both models' predicted combinations investigated through a network-based analysis and identifying as a synergistic combinations in literature. DeepTCM illustrates how natural products such as TCM are a novel path where new drug combinations can be discovered.

The Genomic Evolution of the SARS-CoV-2 Virus and Its Effects

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Teacher: Lori Twehues

Over time, the SARS-CoV-2 virus has evolved. This evolution has been influenced by both the selective pressure from the host's immune system, as well as the natural mutation rate of the virus itself. Tracking the genomic evolution of this virus and its strains, by observing changes at the amino acid and nucleotide level, will allow one to gain a better understanding of the potential impact specific mutations have had on the transmission of SARS-CoV-2. Data collected via sequencing a variety of protein sequences serves as the basis for not only understanding the function of specific proteins within the SARS-CoV-2 genome, but also potential vaccine targets.

Out of 11 proteins that were sequenced, proteins ORF1a, ORF1ab, and the Surface Glycoprotein were found to have the highest frequency of mutations. Proteins ORF6, ORF7a, ORF7b, and ORF8 were found to have the highest conversation, and could potentially serve as targets for therapeutic intervention.

Production and Applications of Biodiesel

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The purpose of this project is to address the increasing prices of fuel. The engineering goal is to provide a comparable alternative to industrial diesel using renewable biodiesel. The hypothesis for this project was that a gallon of biodiesel would cost $3.51 a gallon and would be 7.5% less efficient than petrodiesel. To create the biodiesel, recipes and procedures as well as research on the transesterification process was found. Data was collected by calculating the cost to make the renewable biodiesel and comparing the amount of time diesel would power an engine compared to biodiesel. The results show successful biodiesel made from methanol, but not from ethanol, at a cost of $4.88 per gallon, and that the Biodiesel was 12.9% more efficient than industrial diesel. The results of this project led to the following conclusions: a biodiesel reaction is much more likely when using methanol, the cost of biodiesel decreases as materials are purchased and produced in bulk, and that biodiesel is more efficient than diesel due to the fuel density and presence of oxygen. Current research being done in this field includes research on other possible bases for the biodiesel.

The Development of Gesture-Controlled Technology by Means of Bend-Sensing Carbonic Insolation

Matthew Murphy
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As nations around the world make advancements in artificial intelligence, several professions are now operated by robots, such as rovers and drones. This improves cost efficiency and enhances mass production. In 1989, Young L. Harvill invented the flex sensor, allowing a user to control a robotic hand using hand gestures in a glove with flex sensors. However, these sensors can be relatively expensive, and can cost over one hundred dollars for a simple potentiometer glove, and if one were to apply it to more complex machinery that needs many sensors, the costs can add up overwhelmingly. The goal of this project is to design an alternative method to create these sensors.

Regular flex sensors have an electric current running through a segmented conductor surrounded by a conductive ink and deposited on a phenolic resin substrate. Bending the sensor stretches the conductor and changes the resistance. The flex sensor will then be linked to an arduino, which will run a code that measures this change, which can be used to calculate the bend and mimic it in a robotic object. The new type of sensor will use similar concepts to measure the degree of a bend, except it will use carbon graphite as an insulator, and encase aluminum foil with carbon graphite in a flexible acetate coating, and this sensor will be used to create amperage values for the same process as mentioned previously. The goal will then be to apply this alternative method to a gesture-controlled piece of technology.

Far Out: A Search for Exoplanets

Trinity Shroyer

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The purpose of this engineering project is to design a script in Python that inputs exoplanet candidate data from the NASA archive in order to classify a planet as rocky or gas, thus suggesting further observation. The data set was pulled from the Transiting Exoplanet Survey Satellite (TESS), which uses transit detection. There are two main components to the project: the coding in Python and data analysis. In the end, Python was successfully used to calculate radius, volume, and mass of exoplanet candidates within a csv file. Once categorized into rocky and gas planets, the masses were labeled as "True" or "False" depending on the mass criteria for a rocky planet (<10 Earth masses) or a gas planet (>10 Earth masses). Mass was chosen to be analyzed because the parameter given by the NASA archive is that an exoplanet had to be less than 30 Jupiter masses, and if they were over 30 Jupiter masses they were not counted as an exoplanet. The project was successful after many attempts and showed that a small amount of data represented potential rocky planets, and a majority represented gas planets.

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