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Is the Source of Dark Energy Time Dependent?

Yaz Aubrey

The James Webb Space Telescope, the most powerful telescope in space, has seemingly detected galactic structure formation earlier than expected by current theory. The purpose of this project was to find an explanation for earlier-than-expected structure formation using a quintessence-type theory that assumes the same origin of both cosmic inflation and dark energy. This was done using the Friedmann Equation after replacing the energy density term with a volumetric time-dependent initial energy term meant to represent dark energy. This change was based on the assumption that dark energy was being fed into this universe by another opposite universe at the speed of light. The new dark energy theory included both an inflation regime and a cosmological constant regime as found in the standard model of cosmology, but did not fully match up with the time dependence of the existing Hubble Parameter. This new theory suggests an explanation for changes in early galaxy formation but is not yet successful; however, adjusting the theory could provide a better fit to JWST observations. A better understanding of the universe and its formation would further scientists' understanding of the current contents of the universe and their inevitable end.

Global Navigation Satellite Systems Observations of the Ionosphere During Strong Thermal Emission Velocity Enhancement

Megan Zhang

Richard Chen

Global Navigation Satellite Systems (GNSS) signals experience phase and amplitude fluctuations known as scintillation when traveling through density irregularities in the ionosphere. Positioning methods such as precise point positioning (PPP) require highly-accurate GNSS signal carrier phase measurements: however, scintillation degrades these signals, diminishing positioning accuracy and negatively impacting communication and navigation networks.

We record the first collocant observations of GNSS total electron content (TEC), scintillation, and PPP variation associated with Strong Thermal Emission Velocity Enhancement (STEVE) emissions, a recently-discovered, aurora-like arc characterized by a mauve glow, enhanced temperatures, and enhanced ion flow speed. We used optical imaging data from the Time History of Events and Macroscale Interactions during Substorms all-sky imagers to determine the spatial and temporal dynamics of STEVE. Additionally, we used GNSS receiver data from the University Navstar Consortium to find TEC, scintillation, and PPP during STEVE.

Although the theory of ion recombination suggests that TEC decreases during STEVE, interestingly, we found an unexpected enhancement of TEC associated with STEVE. TEC enhancement closely followed the path of STEVE longitudinally and was localized to STEVE. PPP exhibited enhanced variance locally around STEVE, indicating that the GNSS positioning error increased significantly. We suggest that the TEC enhancement during STEVE creates local TEC structures in the ionosphere that degrade GNSS signals and PPP performance. The TEC enhancement is likely created by energetic particle precipitation and Pedersen drift across STEVE. These results quantify STEVE's impact on ionospheric dynamics and GNSS navigation for the first time.

Detecting Debris Disks Around White Dwarfs through Infrared Excesses

Jessica Liu

White dwarfs are the final evolutionary state of low and mid-mass stars and are ideal targets to study debris disks due to their relatively pure atmospheres of hydrogen and helium. Debris disks are rare astronomical phenomena and are composed of the remnants of asteroids, comets, and planets, and provide crucial insight into the evolution and formation of extrasolar planets. In this study, infrared excesses, which may indicate the presence of debris disks, were searched for from an initial list of 437 white dwarfs from the Sloan Digital Sky Survey Data Release 7. After perform- ing photometry in infrared bands bands and fitting spectral energy distributions (SEDs), 3 white dwarfs with true infrared excess were identified, translating to an occurrence frequency of 0.7%, a rate aligning with previous research. Since less than 100 white dwarfs have been confirmed to host debris disks, these 3 detections significantly increase the known sample and will enable further study into the evolution of planetary systems and the characteristics and composition of these disks.

Analyzing Kink Angle Property in Cosmic Strings Using Computation Evaporation Simulations

Kirthivarsha Sivakumar

Cosmic strings and cosmic loops are hypothetical structures that exist throughout the universe that astrophysicists have been studying for almost 50 years. There have been hypotheses of how these structures act throughout the universe and what their properties are. Attempts have been made to find direct evidence of cosmic strings and loops but have not been successful yet. Currently, in order to study cosmic strings and loops, astrophysicists have been using simulations and simulation data to learn about cosmic strings and loops. In my research, I used simulation data of cosmic strings and loops to analyze the cosmic loop kink angles and how they change as cosmic loops evolve over time in the universe. From analyzing the degree measurements of the kink angles through developing a data analysis program, I found that these angles in cosmic loops decrease over time as the levels of evaporation, which are how much the loops evolve over time through the release of energy. This research is necessary for our understanding today, because cosmic strings and loops are topological defects that were formed during the Big Bang. This perhaps may be a window into string theory and real evidence of the string theory model, which can provide a unified understanding of gravity and particle physics.

Increased Precision in Stellar Parameters of HD189733b and HD209458 Using TESS Light Curves

Jaeyi Song

HD189733b and HD209457 are both canonical exoplanets with deep transits, short periods and bright host stars, allowing us to determine a precise and accurate radius and temperature. We used EXOFASTv2 to run a series of stellar fits and were able to infer HD189733b's radius to 1.1% (0.7585: +0.0088, −0.0086 R□) and its temperature to 1.2% (5141: +61, −60 K) - a factor of 2 improvement in precision over previous studies. Our stellar radius is 2.6 sigma discrepant from its CHARA-measured interferometric value (0.805: +0.016, −0.016 R□) which, we argue, are due to systematic errors in the interferometric radius. HD189733's angular size is only 1.1 mas, and interferometric radius measurements have shown significant disagreements when the angular diameter is below 1.25 mas. Thus, this suggests that the widely accepted stellar parameters are significantly overestimated and less precise than our conclusions. For HD209458, we were able to measure the radius to 1.44% (1.196: +0.019, −0.020 R□) and its temperature to 1.7% (6110: +110, −100 K) - a factor of 2.4 improvement in precision over alternative studies. While HD209458 does not have an available interferometric radius, we determined that our values have a higher level of precision than traditional methods that rely on spectroscopy and theoretical modeling. In this paper, we generalize our procedure so we can accurately and precisely determine the radii and temperatures of stars with high signal to noise transiting planets while carefully accounting for systematic errors.

Utilizing Infrared Spectroscopy to Identify the Limits of Water-Fueled Space Travel

Leila Ohashi

The presence of water in comets and asteroids offers the possibility of extended space travel . Water can be separated into its component elements, hydrogen and oxygen, which can then be used as propellants for spacecraft. This project aims to use infrared (IR) spectroscopy to analyze the presence of water in main belt asteroids and comets, and then to estimate the upper limits of space travel enabled by this energy source. The sun emits light to the asteroid, causing molecules to absorb light. Consequently, the electrons move from a higher level to a lower level due to the tendency to attempt to be less excited. However, as a result, some form of energy must be released in order for the electrons to move to lower levels. The energy is released in the form of photons, which are what are measured on Earth by an IR spectrometer. A single IR spectrum is unique to each organic compound, so elements can be identified using their spectra; an element's spectrum is a type of chemical "fingerprint". Water is most easily identified at a near-infrared spectrum. The amount of water identified from IR analysis of existing asteroids and comets can be used to find the total energy that could be produced, which in turn can be applied to find the maximum distance a spacecraft can travel. Overall, this project gauges the possibility of harvesting energy from small solar system bodies to radically improve human's capabilities for exploration of space and life on other planets.

Assessing Student Proficiency with AI and Evaluating AI Detectors

Bilal Zaki

For school assignments, tools like ChatGPT have been powerful assets for students. ChatGPT has many capabilities, but students use it to assist them in their assignments. In a time when technology is advancing rapidly, integrating Artificial Intelligence (AI) into education has become increasingly important. To the students who participate, I will write a question “Should AI be integrated into education? Why or why not?” on the board. Students will receive a paper to answer the question on and notecards that say AI or Non-AI. If they received Non-AI they can’t use AI in their answer. If they receive AI they can use AI like ChatGPT in their answer. The English Teacher had the most answers correct. In terms of AI detectors, GPTZero did the best. Identifying AI usage in the eighth grade was easy for the teacher, student, and AI detectors. When it comes to the tenth grade it was really hard for the teacher, student, and AI detectors to identify AI usage.

The Swift Project

Sumayya Henshaw

I researched how Taylor Swift's music affects the heart rate, and I found some interesting articles that indeed talk about Swift's positive impact on a person's mental health. After experimenting, I learned that Taylor Swift's music does have an effect on your heart rate. It seems like her pop and country music affect a listener equally, but folk does slow down the listener's heart rate, which can be helpful to know if one is looking for music to relax to.

Visual Communication

Clare McFaul

Communication; one of the most important concepts in our life. Every day we use communication. Without communication, society would be crippled; unable to function efficiently and properly. For some, communication can be difficult. Those with visual or audio disabilities communication is much different. Some use sign language, hearing aids, lip reading, or can only hear the spoken language. For these reasons and many more, it is important that society is fluent and utilizes many types of communication. This project focuses on the effect of visual communication on typical, educated members of society. The hypothesis of this project is if participants are given information through visual communication, then they will score higher and test faster than those who received information through written communication because visual communication is easier to understand and retain. To test this, two separate quizzes were created. One with information presented visually and one with information presented in written form. One hundred people, fifty for each quiz participated to help find the results of the experiment. The expected outcome was that those who took the visual communication quiz would score higher and spend less time on it than those who took the written quiz. This expectation was correct and showed that visual communication is efficient, easier to remember, and more effective than written.

Is What You See Truly What You Get? An Understanding of Subliminal Persuasion Hidden Within the Presence of External Stimuli

Aurelie Laroche

The topic of subliminal perception is one that comes up often in psychology when human perception is being studied . It can be defined as a phenomenon where people are able to detect stimuli that they did not consciously perceive, as the repeated viewing of subliminal stimuli activates multiple groups of neurons that increase neuron communication within the brain. Many psychologists who work within advertising industries try to use subliminal stimuli in order to influence the behavior of their consumers without their knowledge. This action is called subliminal persuasion, where subliminal stimuli is intentionally introduced into an environment in order to try to sway the thinking of a human. However, it can be argued that this is not an effective way to affect human behavior due to it being close to or even below the sensory absolute threshold , which is the smallest limit where a person is able to consciously detect a stimuli with their senses at least 50% of the time. This project is meant to test whether the subconscious detection of subliminal stimuli can influence the way one might think. Participants will be asked to undergo four trials; two watching video and two listening to audio (video and audio created by student researcher). They will be asked to answer a series of questions regarding the given audio/video after each trial. The length of time of the experiment involved for each participant will be about 30 minutes. Before experimentation, the participants were informed that in order to avoid bias, they were not told the full extent of the experiment and will not be until it is complete. In the end, even though the majority of experimental participants did not select many targeted answers, they responded differently than the control group. Through research, it could be suggested that this occurs due to the human mind takes cognitive shortcuts in order to answer the questions, and if someone is able to provide subliminal messages that follow the way people use these shortcuts, then they may ultimately be able to influence them.

Words That Shape the World: A Novel Sentiment Analysis Approach to Quantifying Polarization from U.S. President Rhetoric on Immigration

Ching Hei Andre Leung

Devan Agrawal

Simon Farruqui

In 2024, around 4.2 billion people in 65 countries will engage in elections. Yet, this surface-level engagement belies deeper challenges to democratic stability. Our study employs vector embedding techniques to quantify the influence of political figures' immigration rhetoric on public opinion, policy formation, and societal debates, with a focus on the United States—a principal democracy. Analyzing presidential speeches from 1960 to 2020, we uncovered linguistic patterns that signal an intensification of political communication polarization. This shift towards more extreme rhetoric on social media starkly contrasts with traditional political dialogue and signals potential risks to global democratic efficacy . In dissecting the content of presidential speeches, our research reveals subtle differences in Republican and Democratic presidents ' approaches to immigration, particularly regarding security and economic contributions. Our sentiment analysis, grounded in sophisticated natural language processing methodologies, indicates a downward trend in positive sentiment since President Johnson's administration. Additionally, our data highlight the increasing prominence of Asian immigrants in the U.S. Our sentiment analysis unveils not only inter-party but also intra-party variations in immigration rhetoric, challenging the notion of a binary partisan perspective on Asian countries. By applying a novel sentiment-analysis framework to quantify shifts in political discourse polarization, we provide insights into the changing dynamics of immigration rhetoric and its implications for American democracy.

The Impact of Environmental Factors on Happiness and Stress Levels in Younger Versus Older Populations

Lilah Wallace

This study examined how environmental factors impact happiness and stress in younger versus older populations . Physical environmental factors included exercise and diet, and psychological environmental factors included meditation, sleep, screen time, relaxation time, and weather conditions. Data was collected from 196 human subjects ranging in age from 13-80 years old, with 106 participants in the younger population (13-30 years old), and 90 participants in the older population (31-80 years old). Younger populations are more likely to take risks for a reward that is not guaranteed ; these risks can have negative results and reduce happiness and induce stress (Nuwer, 2012). This risk-taking nature of teens and young adults is driven by the ventral striatum, which controls human outputs of behavior (Aminoff et al) (Abrams, 2022). Younger populations take more risks so they can experience more and learn about themselves . It is expected that both physical and psychological environmental factors will have a more significant impact on happiness and stress levels in younger populations versus older populations due to the younger populations' risk-taking behavior and neurological development. Data was collected via a Google Form survey. The mean, standard deviation, and standard error were calculated for behaviors, happiness levels and stress levels in younger and older populations for all environmental factors; one-tailed t-tests were completed. Younger and older populations had similar average sleep at about 7 hours. However, with less than average sleep, the older population had a statistically significant lower happiness score at -4.61 compared to -3.95 for the younger population (p=0.0154) and a statistically significant higher stress score at 4.12 compared to 3.0 for the younger population (p=0.0041). On average, the younger population exercised for 3.97 days and the older population exercised for 3.51 days per week. With less than average exercise, the happiness scores were very similar for the two populations (p=0.4057). However, the older population had a statistically significant higher stress score at 2.64 compared to 1.02 for the younger population (p=0.0014). Older populations have more days per week when they eat at least one balanced meal at 5.93 compared to the younger population at 4.96 (p= 0.0002). The difference in happiness and stress scores without at least one balanced meal were not statistically significant between the younger and older populations. Without sufficient sleep and regular exercise, the older population experiences a more pronounced increase in stress and decrease in happiness. Future directions of this study would be asking participants questions on anxiety and mood as they relate to environmental factors and including more participants, particularly males and individuals above the age of 61. In this study, the hypothesis was not supported by the data, as the older population's happiness and stress levels were more affected by environmental factors than the younger population.

The Impact of Sleep Deprivation on Cognitive Performance Among Female Middle and High School Students

Carina Fujimoto

Insufficient sleep among adolescents has become a prevalent issue and many students are sleep deprived . It is recommended that adolescents receive at least 9 hours of sleep per night, however, fewer than 8% of students report getting this amount of sleep. Inadequate sleep in adolescents is connected to poor mental and physical health, behavioral problems, and poor academic grades and performance. Altered circadian rhythms, delayed melatonin release, heavy homework loads, and early school start times have a significant effect on teenage sleep patterns . This project compared middle school and high school student nighttime routines and cognitive performance. Due to teenage sleep patterns, it was predicted that students receiving a minimal amount of sleep will earn a lower score on the cognitive test in comparison to students receiving the recommended amount of sleep. It was also predicted that middle school students will have a longer amount of sleep and perform higher on the cognitive test. In order to investigate the correlation between sleep quantity and student performance, participants completed a survey asking for relevant information about their nighttime routine followed by a simple cognitive test. The survey included 4 questions, and the cognitive test included 3 questions. All p-values indicated are calculated by one-tailed t-tests. The analyses performed for participants' responses to survey questions indicated a statistically significant difference between middle school and high school students' sleep quantity (7.4 vs 6.5 hours; $p<0.0001$), amount of homework (1.6 vs 2.6 hours; $p<0.0001$), time spent relaxing (30.3 vs 23.3 mins; $p=0.021$) and time on electronics (21.7 vs 34.3 mins; $p<0.0001$). Middle school students and high school students received similar scores on the pattern recognition (0.67 vs 0.65; $p=0.3959$) and difference identification (4.64 vs 4.74; $p=0.7613$) questions. However, high school students earned higher scores on the word recognition question compared to middle school students (8.66 vs 4.66 words; $p<0.0001$), suggesting, not surprisingly, they are more advanced in their vocabulary and language exposure. In this experiment, the hypothesis was partially supported and the p-values indicate a statistically significant difference between the healthiness of nighttime routines in middle school and high school students, however these nighttime routines showed no statistically significant impact on cognitive performance on this specific cognitive test. Future directions could include recruiting additional participants which may produce more significant results in terms of the sleep quantity to cognitive test performance comparison or incorporating more open-ended questions in the cognitive test to provide a more accurate reflection of cognitive performance in adolescents.

Study Smarter not Harder: The Neuropsychology Behind Studying Techniques in Correlation to Academic Performance of Adolescents

Ananya Mathur

Gianna Nalumansi

Mariyam Patel

Students often spend a lot of time studying, but they don't have a proper structure for how to study. This results in students cramming for assessments, studying the night before or even minutes before a test. When high school students study effectively, their academic productivity will show improvement in comparison to students who have disorganized study habits. If students with poor study habits implement methods that are proven to improve academic performance and recall information in the long term, then these students will improve academically and show growth within their academics.

This behavioral research study took place over the duration of 2 to 3 weeks and utilized 6 popular study techniques proven to increase academic productivity. These study techniques include: the Pomodoro Technique, the Feynman Technique, Spaced Repetition, Mind Mapping, Active Recall, and the SQ3R Method. Each student participant in this research study was assigned a study method to implement into their studying habits. Over the study period, to test the effectiveness of each study method, common trends were looked for within each student's digital lab notebook and weekly responses at virtual meetings.

Overall, the data from this study expressed that the Pomodoro and Feynman Technique expressed a high success rate in terms of effectiveness. 60% of the students who incorporated the technique into their studying habits rated it a 4 on a scale of 1-5 for effectiveness (5 being the highest) and 40% of the students rated it a 5. The key takeaways of the Pomodoro Technique were an increase in concentration and focus as well as a significant decrease in fatigue and exhaustion . As well as having the added pressure of a time limit resulted in most students staying away from distractions such as their phones, a principal cause of students procrastinating and having an irregular sleep schedule. For the Feynman Technique, 75% of the students who incorporated the study method into their studying habits rated it a 4 and the other 25% of the students rated it a 5. The key takeaways of the Feynman Technique were the strengthening of long-term memory and retention. Along with an increase in studying time compared to the amount of time these students spent studying initially. Many participants stated that the technique forced them to organize the material in their heads and simplify complex topics into easier aspects.

Redefining Inflation Forecast: A New Holistic Approach to Analyze Structural and Economic Policy Drivers with Deep Learning

David Guo

Significant inflation forecasting errors and resultant policy missteps by central banks and central governments are among the major root causes of persistent high inflation. The persistent high inflation has created far-reaching economic challenges for society and significantly increased public health and social welfare costs. Particularly, it has severely and disproportionately deteriorated the quality of life for over 60% of Americans who live paycheck to paycheck and struggle daily to make ends meet. This underscores the urgency for a more accurate inflation forecast system and a deeper understanding of inflation drivers.

This research advances inflation forecasting through a new holistic and systematic approach, making the following contributions:

- Improved both the theoretical and practical aspects of existing econometric models related to inflation, addressing the limitations in frameworks such as QTM and Phillips Curve.

- Investigated and created a novel inflation forecasting approach and system that systematically and significantly improved both accuracy and robustness over existing methods. It is both understandable and explainable, with a clear linkage to specific drivers.

- Systematically investigated, identified, and quantified the most important structural and economic policy drivers and effective predictors of inflation. Created the world's first comprehensive database of these drivers.

- Investigated and validated the efficacy of LSTM deep learning techniques in forecasting inflation and identified implementation best practices.

- Investigated and validated the critical importance of data selection and preprocessing for effective inflation forecasting .

- The new system provides actionable insights that enable policymakers and the public to deepen their understanding and develop effective policy solutions to combat inflation.

Keywords: inflation forecasting, deep learning, LSTM, structural inflation drivers, fiscal and monetary policy drivers, data-preprocessing.

Human Comprehension of 4 Dimensional Rotation

Brendan Reed

The question of whether individuals possess the capacity to transcend the confines of three -dimensional (3D) perception and comprehend four-dimensional (4D) constructs remains a subject with sparse scientific investigation. A particular study by Ambinder and colleagues (2009) posits that individuals can acquire proficiency in making spatial judgments regarding the length and angle of line segments within four-dimensional space when viewed in virtual reality settings. This research aims to investigate the possibility of individuals enhancing their comprehension of 4D rotations, specifically focusing on hypercube rotation. The overarching aim of the project is to examine the boundaries of human perception and the cognitive prowess in grasping concepts beyond the realms of everyday environments, utilizing various models. The experimental design spans five days of trials, conducted within a seven-day time frame. Initial proceedings on the first day entail participants completing a preliminary survey and viewing an instructional video explaining 4D concepts and the experimental protocol. On each of the experiment days, participants engage in rotating a 3D cube to match a target orientation in a 3D virtual environment, followed by analogous tasks involving a 4D hypercube in a 4D virtual environment. Post-experiment, participants complete a follow-up survey. The findings of this study indicate a discernible improvement in participants' understanding of 4D rotation, underscoring the human mind's adaptability in comprehending abstract concepts facilitated by model-based approaches.

Does Attractiveness Affect Your Criminal Justice Processing?

Grace Bui

Nina Lee

Yurie Lee

Our project is whether or not there is appearance bias in the criminal justice system. We are studying this because appearance bias is a universal issue that can affect anyone. We chose the criminal justice system because if people are unfairly incarcerated due to appearance bias, their whole lives are ruined. The purpose of our experiment is to raise awareness on this issue. In order to test this, we created two different surveys with 5 detailed scenarios of crimes. For each crime, there were two designated suspects. One was attractive and the other was unattractive. Each survey would have an opposite suspect. We asked that the participants put in the amount of years they think the suspect should stay in jail. After sending this survey out to 60 participants of different ages, races, occupations, and genders, we were able to find that there is appearance bias. In general, unattractive people received higher years than their attractive counterparts.

The Effects of Nature on Stress

Diya Patlolla

Lola Keeney

This research focused on the effects of exposure to natural sounds on stress levels and accuracy during memory tests . When this study was started, as students, we felt like the subject of stress was very close to our hearts, and wanted to find a non-invasive way to assist stressed students during exams and stressful classes. Many students may already have coping mechanisms, such as listening to music or taking a walk, but those are not very accessible during the school day where students are inside almost the whole day. The goal was to prove that if exposure to nature is increased, then students will experience a decrease in stress levels, and if proven, bring this solution to classrooms across our district and beyond. To conduct this research, we issued a 2 part memory test to two different groups, one with access to nature sounds and one without. These tests were issued in a classroom setting under test-like conditions to ensure that the test remained similar to a real classroom exam. Additionally, we also collected data about the stress levels of the participant before and after the test was taken, and asked them to practice some mindfulness and reassess the way that they went about taking their test. Overall, we observed that the stress levels went down more for the group that was listening to the nature sounds than the control group. This is significant because if teachers can adapt their classroom testing experience by playing soft nature sounds in the background, it can help improve student's mental health and even help them recall information better .

Social Space Assay Reveals- F1 and F2 Drosophila Exhibited Sign of Autism Caused by Daily Excessive Consumption of Copper

Suri Hoang

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that is characterized by complex behavioral deficits, including intellectual disability, social disengagement, and hyperactivity. Although many scientists believe that ASD can develop from a combination of strong genetic components and environmental factors, still there is not a single known cause that specifically leads to this disorder. Some researchers have found a positive correlation between a child's body burden of toxic metal and the severity of autism symptoms since heavy metal can have a strong effect on neurological and behavioral effects in humans. As one of the most poisonous and daily found metals, copper is especially necessary for cellular processes. Its excessive consumption in tissue can lead to cancer and many neurodegenerative diseases such as Alzheimer's and Parkinson's. Unfortunately, the specific mechanisms that explain the impact of heavy metal on the development of Autism are not fully understood. Acknowledging the need for more research on the heavy metal impact on neuron destruction, social behavior, or mental health, this research is conducted to focus on the correlation between excessive consumption of copper and the development of autism in the Drosophila model via social assay and testing whether the symptoms of autism can pass along the generation. The result shows that F1 consuming copper are likely to exhibit social distancing compared to F1 consuming basic medium. Moreover, F2 (that was born by potentially autistic parents) does not exhibit social distancing if they stop consuming copper. This social behavior experiment not only implies the positive relationship between consuming copper and the high risk of developing ASD but also suggests one possible way to stop the generation passing of the disorder, which is by simply reducing the child's copper consumption. The review reminds people to minimize exposure to copper in daily life, especially during pregnancy and childhood, to reduce the risk of a range of neurological disorders, including ASD. However, the exact mechanism of copper-induced symptoms of ASD needs further investigation.

Ginsenoside Ck and RK1 Effects on High Intensity Behavioral Patterns of Agression in a Taupathy Model of Alzheimers Disease in Drosophila Melongaster

Jia Anand

Alzheimer's is the sixth-leading cause of death in the United States. Alzheimer’s disease is a progressive brain disorder that is a result of changes in the brain that cause the brain to shrink and the brain cells to die eventually. About 55 million people around the world have dementia, and 60% to 70% are estimated to have Alzheimer’s disease. As Alzheimer's progresses, the likelihood of agitation and irritability increases. A study suggests that as many as 90% of Alzheimer's cases include these types of behavioral changes.

There is no cure for Alzheimer's, but there are treatment options, including drugs that may help treat symptoms. Moreover, standard drugs are expensive, cause side effects, and aren’t promised to work. Thus, an example of ayurvedic treatment, Fermented Ginseng, can be a potential complementary Alzheimer’s treatment to explore.

Hypothesis(es): If a tauopathy model of Alzheimer’s Disease in Drosophila melanogaster are raised on a fermented ginseng-supplemented diet, then they will exhibit reduced anxious and aggressive behaviors more consistently as measured by an aggression assay than those raised on a normal diet.

Chemical Profiling of the Triglycerides in Two Species of Microalages Using a Green Extraction Method

Susan Evans

Recently two species of algae, Spirulina and Chlorella were examined for their triglyceride species and Amino acids to examine their efficiency in biofuels. A green method for extraction using solvents EtOAc/EtOH was utilized. After extracting the lipids from algae samples, an LC-MS was utilized to analyze the data. It was evident that spirulina has shorter carbon chains than those of chlorella. Chlorella tends to have more double bonds than the triglycerides found in Spirulina. The data showed that Spirulina would have lower viscosity and better burn efficiency than biofuel from Chlorella .

Biofuel Potential of Cape Cod Seaweeds

Ella Rosenthal

The planet is warming drastically due to CO2 emissions from the burning of fossil fuels. In addition, our local waterways are being contaminated by excess nitrogen from fertilizers and human waste from septic systems/ agricultural runoff, this issue is especially prominent on the Cape. The excess nitrogen prompts the uncontrolled growth of seaweeds and other algae which can contribute to hypoxic environments. Can we use this excess seaweed to produce a carbon-neutral replacement for fossil fuels? In this study, I will explore the potential for ethanol production from local Cape Cod seaweeds.

Modeling Chemotherapy-Induced Stress: Investigating the Role of Vitamin C in Alleviating Hydrogen Peroxide-Induced Oxidative Stress on Yeast Cells

Jacklyn Omere-Okundaye

Although chemotherapy is critical for cancer patient management, oxidative stress caused by these drugs greatly impacts quality of life. Oxidative stress occurs when there is an abundance of free radicals within a tissue. Free radicals are unstable and reactive atoms/molecules that have one or more unpaired electrons. Antioxidants, such as Vitamin C are molecules that can neutralize free radical production. The aim of this study was to determine the effect of Vitamin C on the viability of yeast cells prior to or after exposure to hydrogen peroxide (H202). H2O2 is known to facilitate free radical formation in both human and yeast cells. A 22 factorial design was used to determine the interaction between Vitamin C concentration and when Vitamin C was administered, relative to H2O2 exposure. Light microscopy was used to determine cell viability. Two Vitamin C concentrations were tested (0.1 and 1.0 mmol/L) at two time points (pre and 24h post) H2O2 exposure. Four control groups were included (cells exposed to both concentrations of Vitamin C, cells exposed to H2O2, and untreated naïve cells). All groups were run in triplicate. The results of the study indicate a significant interaction ($p<0.05$) between Vitamin C concentration and exposure time. Cells incubated with 1 mmol/L Vitamin C 24h following H2O2 exposure exhibited significantly ($p<0.05$) greater viability, relative to the other experimental groups. However, the viability was significantly ($p<0.05$) lower than that observed for naïve cells. The results suggest that Vitamin C may help reduce oxidative stress caused by external factors, such as chemotherapy.
Keywords: Cancer, Chemotherapy, Cardiotoxicity, Antioxidant, Vitamin C

Self Healing Concrete Using Bacteria

Leyna Nguyen

Concrete is a widely used material in construction due to its durability and low maintenance properties. However, it is susceptible to weathering. Since concrete is a porous material, water can seep through and create internal air pockets, overall weakening the concrete structure. Traditionally, to address this issue, the concrete would have to be completely replaced, which is a costly and labor-intensive method.

This study proposes the idea of implementing microbial-induced calcium carbonate precipitation (MICP) into the construction world. The bacteria tested (Bacillus Subtilis, Rhodospirillum Rubrum, Ensifer Meliloti) are suspended in a PBS urea solution. The calcium carbonate-producing bacteria is then mixed into a wet concrete mixture (water and dry concrete mix). When the concrete samples are set, the bacteria would form a “chrysalis” around itself. When water is added to the samples, the urea and the bacteria are rehydrated and calcium carbonate is produced to fill in the internal air pockets, creating “self-healing concrete”. $CaCO_3$ production is measured through initial and final mass comparison. Before weighing the final mass, the water weight is driven off.

The results show that $CaCO_3$ production is evident in the bacteria concrete samples, which is depicted by a percent increase comparing the initial mass and final mass. Future testing would involve testing durability, $CaCO_3$ production in different environments, and different methodology in creating self-healing concrete. This study contributes to the growing body of research on sustainable construction materials and lays the foundation for future advancements in self-healing concrete.

Naturally Made Cleaning Products Are Better for the Home Instead of Using Harsh Chemicals

Shanay Love

The purpose of this experiment was to investigate how effective eco-friendly, homemade disinfectants would be when compared to traditional disinfectants like Lysol and Clorox in killing household germs , school germs and E. coli bacteria. Using harsh chemicals to clean one's home has some serious health issues not to mention the environmental problems of disposal. This experiment wanted to find and determine if a more natural homemade version that is eco-friendly is a better option for cleaning. The experiment used homemade disinfectants prepared from Castile soap, vinegar, hydrogen peroxide, and essential oils, testing their antibacterial activity against E. coli. Results were compared to the commercial disinfectants to determine if natural eco-friendly alternatives could give the same or better results. The hypothesis suggested that these eco-friendly disinfectants would be as effective and even better than traditional ways of cleaning while also being more affordable and environmentally friendly. The hypothesis was supported.

Alkylammonium Modified Photosensitizers Achieve Lysosome-Precision Photodynamic Therapy: Implications from Molecular Dynamics Simulations

Xi He

Photodynamic therapy (PDT) is one of the developing treatment modalities that has been clinically approved for cancer treatment. It uses an organic photosensitizer that harnesses the light energy and converts intracellular oxygens to reactive cytotoxic species. The resulting chemicals can then damage cells and lead to cancer cell death. However, the existing photosensitizers do not show cell or organelle specificity, which lowers their treatment outcomes. In this project, we used molecular dynamic simulations to demonstrate that a straightforward alkylammonium modification on photosensitizers is able to endow conventional photosensitizers with the ability to target and accumulate in lysosomes. We observed that the oxidized membrane induced by modified BODIPY would yield poration with larger pore diameters and higher resistance to membrane repair by diffusion by MD simulations. This acquired lysosome specificity may achieve the lysosome-precision PDT experimentally, which is expected to enhance the PDT outcomes. More importantly, such organelle-precision modifications have the potential to be extended beyond PDT treatment and make contribution to drug discovery and eventually cancer treatment.
Keywords: Cancer treatment, organelle-precision, photodynamic therapy, molecular dynamics simulations

Using Clustering Algorithms to Predict Whether Phytochemicals are Cancerous or Anti-Cancerous.

Arnav Chetty

Chemicals found in naturally occurring foods can be beneficial in treating cancer, but sometimes also carcinogenic. This data-mining project uses a clustering graph approach applying the k-means algorithm prefaced by simple statistical analysis such as averages and percentages. Clear groupings of phytochemicals were identified based on six different chemical properties: molecular mass, refractivity, polarizability, Pka strongest acidic, electron donor count & solubility. The values of these chemical properties provide a scientific basis to predict whether a phytochemical is cancerous or anti-cancerous. Using the data found, a deep neural network was created that can predict if a phytochemical is cancerous or anti-cancerous. Using all the data 3 phytochemicals were chosen to create a theoretical pill to theoretically prevent breast cancer.

Acidity on Tooth Enamel Decay

Hemam Henok

Maria Alves

Roua Shaikhi

Enamel loss occurs with highly acidic liquids and causes many to wonder what quickens the process of enamel erosion. Highly acidic juices with low pH levels can create a huge impact on tooth enamel, by changing its transparency, coloration, and smoothness furthering its damage into cracks and tooth decay. The main aspect of this experiment is to help people who suffer from weak enamel gain a better understanding of how much damage their drinks can impact their teeth . This experiment's factors taken into observation were the discoloration, smell, texture, and shape. When conducting this experiment it took a spawn of 6 days which involved collecting 18 human teeth and taking observations. Arrange experimental and control groups into a chart and 18 clear cups. Fill the cups with 20 mL of liquids and leave the tooth inside for 20 minutes simultaneously. After the timer ends, remove the tooth carefully and place into it's labeled container. Place the clear containers with the tooth inside into an incubator at a temperature of 98.6 degrees for 24 hours. Then remove the teeth from the incubators after 24 hours and take photographs and observations, analyzing any change in the teeth's color, smell, texture, and shape. When this experiment was conducted it was found that orange juice has the greatest and quickest effect on enamel loss. Furthermore, our hypothesis was rejected as it was previously thought that lemon juice would have a greater impact due to its high acidity compared to the other juices experimented with.

What Happens To Your Teeth When Drinking Different Beverages?

Aaron Paglia

Madelynn Battista

Sarhea Johnston

In this project, you place six hard boiled eggs into six different drinks that consist of water , minute maid lemonade, coca cola, coffee, sprite and apple juice for a three day time period. The beakers holding the drinks with the eggs inside them are there to demonstrate what happens to your teeth when you drink certain drinks over time. It shows what happens to your teeth by cracking, changing color, and dissolving to show cavities, and erosion in your mouth. This helps to teach people to have good dental hygiene and take care of their teeth by staying away from drinks with more sugar or being smart with how often you are consuming those drinks.

A Novel Spectrophotometric Method of Non-Invasive Blood Glucose Monitoring for Type II Diabetes Using Correlated Electrolyte Concentrations

Anoushka Nair

Dylan Striek

Type II Diabetes has become increasingly prevalent, with over 462 million individuals suffering from the disease worldwide. However, current glucose monitoring methods necessary for maintaining a healthy blood sugar threshold are painful, costly, and unsustainable. This project seeks to develop an alternative method through the establishment of a novel, spectrophotometrically-obtained correlation between glucose and electrolyte concentrations (potassium, sodium, and phosphate) in the blood.

Silkworms were used as a diabetic model for experimentation, with different groups fed varying sugar-to-food ratios of 1:12, 1:9, and 1:6 to ensure diversity in glucose levels, as well as a 0:1 control group. Absorption values at optimal wavelengths (established in Phase 1) for each electrolyte as well as their corresponding glucose concentrations, obtained using a glucometer, were recorded from centrifuged silkworm hemolymph.

Polynomial regression was employed to obtain the correlative equation relating both variables and the R^2 value (correlative strength). All three electrolytes fulfilled the criteria for a strong model with R^2 values exceeding 0.9, indicating high correlations between electrolytes and glucose in the hemolymph. Additionally, ANOVA tests were performed to ensure that an increase in one electrolyte concentration did not significantly correspond with another, further proving the absorbance values were collected based on electrolyte concentrations and not variable color changes.

These correlative equations were applied in our functional prototype; a portable spectrophotometer that approximates glucose concentration using electrolyte absorbance obtained using a photodiode and LED lights corresponding with the absorption spectra of the electrolytes.

An Examination of the Neuromuscular Impact Induced By Hypermagnesemia & Hypercalcemia in Caenorhabditis Elegan Mutants: A Translational Genomic Model for Paralytic Drug Testing

Srilakshmi Venkatesan

Within the United States alone, there are over forty million major surgeries that are performed each year, using anesthesia and paralysis. However, there have been 100s of reports that have been filed reporting the injuries, errors, and long term effects that many NMBAs have created. In fact, according to the IARS approximately 40% of patients in the postanesthesia care unit exhibit symptoms of residual neuromuscular blockade and over 6x increase in the risk of death seventeen times risk of AAGA. To mitigate some of these effects, reversal mechanisms for paralytics have been under development but adverse reactions whether it be nausea, vomiting, dry mouth, tachycardia, dizziness, or hypotension have greatly limited their use. The current models for NMBAs utilize vertebrates which are inefficient for cost, scalability, and ethicality. In my previous work, I determined Caenorhabditis Elegans would be an effective model for paralysis through 1) determining if excess magnesium exposure could independently induce paralysis by lessening the thrashing effect expressed in liquid solutions by C. Elegans and 2) determining if the reversal of magnesium related paralysis could be acquired through the uptake of calcium, observed by a restored thrashing effect in the C. Elegan model. The results of that study found that increased magnesium concentrations had decreased the thrashing of C. Elegans and that calcium under certain concentrations that increased with increases in magnesium concentrations was capable of reversing the paralytic effect observed in worms by the nematodes. However, to determine if the mechanism of action of magnesium and calcium was occurring at the neuromuscular junction, the intent of this study was to determine if Caenorhabditis Elegans would be an effective model for gene based paralytic testing and develop a greater understanding of genes in the neuromuscular junction. It was done through 1) to determine if excess magnesium or calcium can affect and/or reverse the paralysis in an ace-2a gene mutation of C. Elegans, observed by a restored thrashing effect and 2) to determine if excess magnesium or calcium can affect and/or reverse the paralysis in an unc-2 gene mutation of C. Elegans, observed by a restored thrashing effect. The results of study found that increased magnesium concentrations were able to restore paralysis in these mutations, effectively demonstrating that C. Elegans are an effective model for paralytic testing at the neuromuscular level.

Bioflim Development on Bottle-Brush Electrodes for the Enhanced Reduction of Atmospheric Carbon Dioxide

Abigail Royo

Catherine Crane

This study investigates the correlation between biofilm growth of Shewanella oneidensis and the reduction of atmospheric carbon dioxide. The hypothesis states that a material conducive to both carbon dioxide reduction and the growth of Shewanella oneidensis bacteria could result in excess energy we might be able to harness and use while simultaneously decreasing atmospheric carbon dioxide. Originating from research initiated in November 2022 that focused singularly on creating a material S. oneidensis could thrive on, this project aimed to do the same with the addition of conductivity to the material. The material can be characterized by high levels of reduction of atmospheric carbon dioxide, greatly outweighing its conductive properties. These findings shifted the long-term goals of this project to integrating our novel material into a microbial system with the potential for electrochemical applications. The methodology involves the creation of a specialized material using methyl methacrylate, diethylene glycol, isopropyl alcohol, Nile blue coloring, and carbon fiber powder; followed by the formation of bottle-brush electrodes by mixing the solution with a silicone elastomer; and conductivity testing using cyclic voltammetry. Nile Blue coloring was chosen for this project because of the proven fact that S. oneidensis thrives off of this carbon-based complex, and carbon fibers were chosen because of their unique ability to organize the material in a way that makes conducting electricity effortless. Safety precautions include properly handling and disposal of hazardous chemicals and biological materials, ensuring the integrity of the experimental process and environmental safety. Our graphs prove the material we have created to be a catalyst for carbon dioxide reduction, as well as a material made with substances the S. oneidensis could thrive on, and further research will attempt to alter the material to increase conductivity while developing catalytic capabilities.

First Animal Study On Novel Drug Candidates Targeting Alzheimer's

David Priefer

Kais Guessab

Rishit Shekhar

Alzheimer’s Disease (AD) is a devastating neurological disorder under the family of dementia. Currently, there are over 55 million people globally suffering from this ailment. Until recently, no treatment targeted the underlying cause of AD, which is hypothesized to be the amyloid beta plaques found within the brain. The recent introduction of monoclonal antibody therapy has ushered in new possibilities of helping these individuals afflicted with this disease. Unfortunately, although this approach removes the plaques, these patients are predisposed for them to return, hence the need for a maintenance drug is being actively investigated. A recent publication reported on the development of a variety of extended chalcones that demonstrated the ability to prevent plaque formation, although only in vitro. We were able to conduct the first animal study on their three most promising compounds. We tested these on an AD modeled, genetically modified Caenorhabditis elegans (C. elegans) that were predisposed to develop the aforementioned plaques. We were able to test all three compounds at multiple concentrations and at multiple time points after exposure to these drug candidates. All three compounds displayed either partial or complete reversal of the physiological marker of these genetically modified C. elegans, specifically, a lack of mobility. One particular compound, the chloro analogue of the extended chalcone, had the most noticeable improvement with 93% and 100% of the C. elegans displaying normal mobility at the 1000μM concentration, at 48 and 72 hours, respectively.

A Novel Solution to Degranulation: Phosphate-Caffeine Buffer Inhibits Exocytosis and Increases the Yield of Fungal 1,3-β-d-Glucan (BDG) Biomarker Detection Reagent, Limulus Amebocyte Lysate (LAL)

Mengmeng Zhang

Sophia Zhang

Limulus Amebocyte Lysate (LAL) is widely used for endotoxin detection in vitro and for diagnosing invasive fungal infections in clinics. Previous data showed that the caffeine collection solution prevented degranulation, and caffeine-derived LAL worked in both the chromogenic test and turbid-metric method assays. However, the cell pellets collected by caffeine collection solution aggregated after re-suspension in 5 mM CaCl2. Therefore, we developed the PBS-caffeine bleed solution to evaluate additive effects; no similar phenomenon occurred with the PBS solution. We conducted experiments to test the results of the PBS-caffeine solution on the degranulation during the bleeding procedure, where six crabs were bled once a week for a total of 60 crabs by the PBS-caffeine collection solution. The cell pellets were re-suspended into 5.0 mM CaCl2. Both chromogenic and turbid-metric assay methods tested the LAL activity. According to the results, the PBS-caffeine collection solution prevented degranulation for over four hours and produced a higher-than-standard activity yield than the standard sodium-chloride-derived LAL. In addition, there was no discernable impact on the activity yield of crab size, and the PBS-caffeine collection solution reduced amebocyte aggregation and clot formation during processing. We also determined the biochemical characteristics of PBS-caffeine-derived LAL and observed that PBS-caffeine-derived LAL worked in both the chromogenic and turbid-metric assays. Overall, PBS-caffeine collection solutions prevented amebocyte degranulation during the blood collection and processing procedure. Significantly, PBS LAL is functional in both the chromogenic test and turbidimetric assays.

Using the B6Ei.LT-Y* Mouse Model to Investigate the Contribution of Sex Chromosomes within the Kiss1+ Neurons of the Preoptic Hypothalamus.

Isabella Adarme

Abnormal pubertal timing puts both males and females at risk of shorter height, angina, several cancers, hypertension, decreased lifespan, along with Type 2 Diabetes, and social and mental health issues (Vlassof, 2007). Pubertal timing and reproduction is largely regulated by three main neuronal populations in the hypothalamus: the Gonadotropin releasing hormone (GnRH) neurons and two populations of Kisspeptin (Kiss1) expressing neurons that can be distinguished by their anatomical location. This study focuses on the Kiss1+ neurons within the anteroventral periventricular (AVPV), which have been extensively reported to be sexually dimorphic, such that there are more of these neurons in females. Here, I use the B6Ei.LT-Y* mouse model to investigate if the previously reported sex difference in the number of these Kiss1+ AVPV neurons is affected by sex chromosome complement. The B6Ei.LT-Y* is a mouse strain that carries an abnormal Y chromosome derived from the LT/Sv strain (The Jackson Laboratory), which allows us to generate four distinct karyotypes of animals, XO and XX females and XY* and XXY males. Here, I show that animals of the XXY and XY* genotype had fewer Kiss1+ neurons than their female littermates. Within the female XO and XX genotype animals, qualitatively it appears that the XO females had fewer Kiss1+ neurons than the XX females, although further investigation would be needed. Therefore, we conclude that the major sex difference in the number of Kiss1 neurons is linked to presence of a Y chromosome, however that within gonadally female animals an additional sex chromosome may affect the development of this reproductive axis. Ultimately, the use of this unique mouse model will build on our understanding of sex chromosome's impact on the development, composition, and function of the brain, particularly the role of the additional X and Y chromosomes on these processes.

Observing the Effect of Microplastics on Zebrafish Macrophages

Taleena Gonneea

Microplastics have emerged as a human health concern, prompting scientists to study their effects on humans. Using human subjects in these experiments proves unethical, so scientists use zebrafish to test the adverse short- and long-term effects of microplastics, due to their genome similarities with humans. This experiment evaluated the effect of polystyrene nanoplastics on D. rerio's developing immune system by assessing embryonic macrophages. It was hypothesized that the caudal hematopoietic tissue (CHT), a region where stem cells migrate after fertilization, would produce the largest amount of macrophages performing phagocytosis. At 3 days post fertilization (dpf), D.rerio were injected with 2 nL of 50 nm wide nanoplastics, and then imaged in two regions, the non-CHT region (Section I) and CHT region (Section II), at 3dpf and 4dpf to evaluate macrophage count and sphericity level using Imaris software. The non-CHT section (Section I) produced a larger amount of macrophages from 3dpf-4dpf, with a higher overall sphericity, indicating a higher rate of phagocytosis in contrast to the Control. In the CHT (Section II), the Control group produced a higher count and rate of phagocytosis between both days, with the Nanoplastic group having less macrophages and lower overall sphericities. The experimental results did not support the hypothesis, with the nanoplastic non-CHT section having a higher macrophage count with higher sphericities. Potential developmental factors could have been influenced by the nanoplastics, however because of lack of nanoplastic data, these hypotheses cannot be supported, and the exact effect of nanoplastics on humans remains unclear.

Identification of Potential Biomarker and Survival Analysis for Hepatocellular Carcinoma Utilizing Bioinformatics Approach : An Investigation Utilizing Cancer Datasets

Agastya Sarmah

Liver Hepatocellular Carcinoma (LIHC) is a leading cause of cancer-related deaths globally. Although a range of treatment options are available, LIHC presents significant challenges to both patients and their healthcare providers. This study explores genomic and transcriptional alterations in LIHC, aiming to identify biomarkers and therapeutic candidates. The study particularly focuses on a set of eight cancer and/or stem cell-associated genes crucial for treatment resistance, survival, and metastasis, which are transcription factor genes POU5F1, SOX2, NANOG, KLF4, SALL4, and ABCF1, and stress-related genes G3BP1 and G3BP2. We utilized in our study a variety of publicly available bioinformatics tools, such as The StanfordCancer Genome Atlas Portal, cBioPortal, UCSC Xena, TNMplot, and The Human Protein Atlas to analyze the TCGA PanCancer dataset and other open-access cancer datasets to examine genomic and transcriptional changes of these genes in LIHC patients. Additionally, we used BCSCdb to query the potential of these genes as cancer stem cell (CSC) biomarkers in LIHC. Finally, we used DepMap and DepLink tools to identify genetic dependencies and biomarker potentials for this set of genes. We identified new genetic and functional associations between ABCF1 and POU5F1, and ABCF1 and UBA52 in LIHC. Although the study provides valuable insights, further research is crucial to delineate the role of these genes in CSC plasticity, therapeutic resistance, and their potential as biomarkers or therapeutic targets in LIHC.

RBC Folate's Effect on Cardiovascular Disease

Zimon Li

This study aims to explore red blood cell (RBC) folate levels as an indicator of cardiovascular disease in multiple demographics of people. Data from the prospective cohort study of the National Health and Nutrition Examination Survey (2017-2020) was analyzed. The association of coronary heart disease (CHD) risk with RBC folate was estimated using logistic regression, adjusting for multiple variables such as age, race, sex, poverty income ratio, smoking status, BMI, and access to health insurance. A total of 3271 patients with RBC folate data that fit the data parameters were included. There was a significant trend between increased RBC folate levels and decreased risk of CHD disease ($p < 0.035$). Compared with the lowest quartile of RBC folate, the multivariable adjusted odds ratios and 95% confidence intervals for CHD were 0.68 (95% CI 0.28 - 1.67)for the second quartile, 0.47 (0.16 – 1.37) for the third quartile, and 0.27 (95% CI 0.09 - 0.85) for the highest (fourth) quartile. In conclusion, higher levels of RBC folate are associated with a decreased risk of CHD in this cohort.

Keywords: Red Blood Cell (RBC) folate, Coronary Heart Disease (CHD), National Health and Nutrition Examination Survey (NHANES)

Inhibition of Melanin Synthesis and Anti-Inflammatory Effects of a Novel Leuconostoc mesenteroides subsp. Derived Exosomes Separated from Camellia japonica Flower

Husang Lee

Leuconostoc mesenteroides, gram-positive cocci, are known to be the lactic acid bacteria that are widely found in fermented products. In this research, a novel colony of L. mesenteroides subsp. was discovered in Camellia japonica (DB) flower for the first time and cultured. Through this research, it was validated that exosomes extracted from L. mesenteroides had their significant effects on anti-inflammation and anti-melanogenesis. These exosomes, at concentrations of 4.44 × 10^8, 8.88 × 10^8, and 1.78 × 10^9 particles/mL, reduced the activity of nitric oxide and PGE2 while not having to decline the growth of Raw 264.7 macrophages. In addition, proinflammatory cytokines, such as IL-1β, IL-6, and TNF- α, were rarely expressed, and the proof of which L. mesenteroides derived exosomes inhibit the expression of iNOS and COX-2 particles was substantiated via Western blot analysis. The identical exosomes were tested for melanin synthesis in B16F10 melanoma cells, where they had no toxic effects on the cells at the concentrations of 1.78 × 10^9, 3.55 × 10^9, and 7.10 × 10^9 particles/mL, and it was confirmed that melanogenesis process was suppressed by reducing the activity of tyrosinase. Through Western blot analysis, it was demonstrated that Microphthalmia-associated transcription factor (MITF) particles were evidently reduced, ultimately repressing melanin production. This research thus proves the efficacy of a novel DB exosome as a strong whitening and anti-inflammatory medicine.

Key Words: Anti Inflammation | LPS | MITF | Melanin | Tyrosinase | Camellia japonica | Leuconostoc mesenteroides

Silent Protectors: The Covert Transformation of Angiogenin in Cancer Defense

Vera Medvedeva

Angiogenin is a small 123-amino-acid long protein essential in vertebrates due to its angiogenesis activity - promoting blood vessel growth. Angiogenin cleaves certain tRNA molecules and thus reprograms translation to adapt to cellular stress conditions. Overexpression of Angiogenin is often associated with cancers as they rely on neovascularization. By contrast, inactivating mutations in Angiogenin are associated with ALS, Parkinson's and Alzheimer's disease. In 2023, it was reported that Angiogenin is activated by ribosomes, which bind the protein and rearrange its catalytic C-terminal tail, increasing the enzymatic activity by several orders of magnitude during stress. Under normal cellular conditions, however, angiogenin is kept in check by the RNase/Angiogenin inhibitor protein, which occludes Angiogenin's active site and prevents cleavage of tRNAs.

I proposed that increasing the activity of Angiogenin by mutations can yield therapies that act by (1) overwhelming cancer cells by excessive tRNA cleavage or (2) treat neurodegenerative diseases caused by inactivating Angiogenin mutations. I introduced two point mutations in Angiogenin's C-terminal tail — Q117G and R121H — and tested the purified mutated proteins in several assays.

It was exciting to find that Q117G mutation makes Angiogenin more active off the ribosome, promising to yield a constitutively active variant. The R121H mutant, however, retained catalytic activities similar to wild-type Angiogenin in most assays.

I then assessed mutants' activities in cancer cells. My preliminary findings suggest that the Q117G mutant cleaves tRNAs better in cells. Interestingly, the cells grow and divide faster when either mutant is added. This suggests that the mutants may have a therapeutic value in neurodegenerative diseases, restoring the development and growth of malfunctioning neurons. To make more rigorous conclusions on this end, brain tissue or cultured brain cells should be tested. Furthermore, I will test different cancer cell lines, whose cellular uptake and Angiogenin turnover differs from those tested, rendering them more sensitive to the activated Angiogenin mutants.

Keywords: Angiogenin, cancer, neurological diseases, point mutation, tRNA cleavage

Dopaminergic Synapse Organizing Molecules and Their Implications for Parkinson's Disease

Remy Kim

Parkinson's Disease (PD) is a debilitating neurodegenerative disease characterized by the progressive loss of dopaminergic neurons in the brain's nigrostriatal pathway. This pathway relies heavily on the Smad1 molecule for the development and maintenance of dopaminergic synapses. While much of PD research focuses on behavior or cell death, there exists relatively limited information on dopaminergic synapses in PD. My research aims to better understand the molecular basis of PD development, specifically, whether dopaminergic synapse deficits occur prior to axon and cell death. I explored the timeline of PD progression by performing immunohistochemistry on striatum sections of MCI-Park brains, a progressive PD mouse model, to observe dopaminergic synapses and axons. The first time point tested was 3 days postnatal (P3), at which point MCI-Park mice displayed healthy axons. At 21 days postnatal (P21), I observed that both synapse and axon deficits had started, but cell death had not. Thus, I concluded that both dopaminergic synapse and axon deficits occur before cell death in MCI-Park mice. Furthermore, through immunohistochemistry on P21 sections, I observed that MCI-Park midbrain cells showed reduced Smad1 activity. Thus, I hypothesized that PD affects dopaminergic synapse formation in the striatum by modulating Smad1 activity in midbrain dopaminergic neurons. Through this experimentation, I have laid out a PD progression in MCI-Park mice where Smad1, synapses, and axons all begin showing deficits between P3 and P21. Further research is required to determine whether P21 deficits may be prevented or lessened by the overexpression of Smad1 at P3.

Keywords: Parkinson's disease, nigrostriatal pathway, Smad1, MCI-Park mice, dopaminergic synapse deficits, axon death, cell death, Parkinson's treatment

Identifying a Novel, Inexpensive, and Noninvasive Biomarker for Fibromyalgia: Using Metabolomics, Genomics, and a Drosophila melanogaster Model

Pranav Addanki

Fibromyalgia (FM) is a complex disease that is mainly characterized by chronic musculoskeletal pain throughout the body, disturbances in sleep and feelings of fatigue, cognitive disturbances, sensory hypersensitivity, and constipation/diarrhea. It is the most common cause of chronic widespread pain in the United States, and females are four to nine times more likely to be diagnosed with the disease than are men. Fibromyalgia remains a complex and poorly understood condition despite its prevalence across the global population.

In this novel study, fMRI scans were analyzed to study the effects of fibromyalgia on various regions of interest (ROI) in the brain and statistical analysis was performed by grouping them to major brain regions. Fibromyalgia showed statistically significant effect on the Cerebrospinal Fluid (CSF) volume for all of the combined Anterior Cingulate Cortex (ACC), Insular Cortex, Prefrontal Cortex (PFC), Amygdala, and Brainstem regions measures.

CSF metabolomics data of fibromyalgia subjects was analyzed and the top metabolites with the highest significance were identified as rapid biomarkers that can provide reliable diagnostic tests for fibromyalgia. Metabolites 5-HTP (5-Hydroxy-L-tryptophan) and 5-HIAA (5-Hydroxyindoleacetic acid), 1-Methylhistidine, Deoxyuridine, Creatinine, 2-Hydroxybutyric acid showed statistically significant differences in fibromyalgia subjects when compared to the control subjects.

This comprehensive study also performed analysis of single nucleotide polymorphisms data and identified gene mutations. Analysis of Genome-Wide Association Studies (GWAS) showed that the alterations in the genes involved in the serotonin pathway and specifically genes related to 5-HTP Synthesis and Transport (TPH1, TPH2, GCH1, and SLC6A4) are more likely to be mutated in fibromyalgia. In addition, GWAS analysis also showed that the gene ADCYAP1 related to Serotonin Receptor Signaling and SULT1A1 related to Serotonin Degradation and Metabolism are also likely to be mutated in fibromyalgia.

To simulate the effects of fibromyalgia in vivo, Drosophila melanogaster (fruit flies) were subjected to fatigue and sleeplessness in three trials. All the experimental groups displayed symptoms of fibromyalgia after the experimental period. However, genetically modified Drosophila, when subjected to the same conditions, did not exhibit symptoms of fibromyalgia.

The results of this study will contribute to a deeper understanding of the metabolic and genetic mechanisms underlying fibromyalgia and provide potential avenues for further research and therapeutic development.

Exploring the Interactions Between Peritoneal Dendritic Cells and T Cells: Implications for Cancer Metastasis

Bolin Miao

Ovarian Cancer (OC) is a formidable challenge as a gynecological malignancy with ascites, the abnormal accumulation of fluid in the peritoneal cavity, serving as a clinical hallmark of advancement and metastasis. While OC immune analyses focused on solid tumors, little is known about malignant ascites inhabitants during peritoneal metastasis. Here, we focused on a single-cell landscape of the OC ecosystem in malignant ascites with comparison to tumor sites. Our data analysis revealed that comparing to the immunosuppressed tumor, ascites contained less exhausted, more memory- like T cells, which correlated with prolonged survival in stages III/IV OC. Furthermore, we characterized the substantial interactions between dendritic cells and T cells. Lastly, an in vitro dendritic cell culture system from Peripheral Blood Mononuclear cells (PBMCs) for potential novel cancer vaccine design was explored. Taken together, this study revealed T cell memory and effector potential amidst immunosuppressive pressures in ascites and provided valuable insight into the cross -talk between dendritic cells and T cells that potentially contributes to the unique T cell profile in the ascites ecosystem .
Keywords: Ovarian Cancer (OC), metastasis, malignant ascites, dendritic cells, T cells, cancer vaccine

Eggstraordinary Decay: A Comparative Analysis of Various Types of Drinks on Eggshell as a Model for Tooth Enamel.

Lilya Fouda

This study investigates the effect of carbonated drinks on the enamel of the human tooth by immersing eggs , as a model of tooth, in carbonated drinks such as Fanta, Sprite, Coca Cola in addition to juice (Capri Sun), and water for comparative analysis. Each egg will undergo a five-day immersion period, with daily observations extended over seven days. This approach allows for a controlled exploration of how various carbonated and non- carbonated beverages may affect the enamel-like structure of the egg, raising awareness on potential implications for human dental health. The result shows a substantial weight increase observed in eggs immersed in water, cocacola, and Fanta which contradicts the results for eggs immersed in Sprite showed a decrease in weight which contradicts the suggested hypothesis. The recognized factors influencing these outcomes, including osmosis, solution concentration, and chemical reactions, emphasizes the interactions between various beverages and eggs.

Does Humidity Level in the Classroom Affect Bacterial Growth and Transmissivity?

Kyle Levy

In the aftermath of the lamentable events triggered by the COVID-19 pandemic, global attention has been decidedly heightened toward the escalating health crisis not only within national borders, but on a global scale. While the prevalence of bacterial transmission and growth is nothing new to the human population, the magnifying glass enforced through the pandemic on illness transmission has forced us to more closely examine, observe, and document the issue. Regrettably, the undeniable reality is that respiratory and other bacterial illnesses are spreading unchecked among school children throughout the nation. While the American school system is no stranger to being a hub for the sharing of germs , the emerging matter of increased infection rates across the country is something that desperately needs attention. The problem is not just prevalent in a few parts of the country, but also deeply intertwined with MV, as noted by MVRHS school RN Mike Savoy. In a recent interview, Savoy remarked on the considerable surge in respiratory bacterial illnesses at MVRHS among the past few years. While there are many potential solutions such as a federal push for increased bacterial vaccinations, or campaigns to push for better cleaning methods, both options entail significant expenses, and necessitate the establishment infrastructure system to be built essentially from the ground up. Alternatively, a far more straightforward, yet remarkably effective solution is available. Conducting experiments involving bacterial cultivation within a chamber specifically engineered to regulate relative humidity, I tested various levels of rh including 25%, 35%, and 45% to ascertain the range in which bacterial growth is minimized. By supplementing experimental data produced at MVRHS with research conducted across the world, it can be deduced that the optimum conditions for curbing bacterial growth and transmissivity (areas with lower humidity lead to drying-out of the sinuses, which makes it easier for pathogens to enter the body) are in a range between 40-50% rh. The implementation of humidity regulation systems in classrooms nationwide to maintain levels within the aforementioned range presents a feasible and potent strategy for significantly mitigating bacterial growth and transmission. This approach promises a brighter future for the leaders of tomorrow, fostering a healthier and more conducive learning environment across the country.

Computationally Derived Average Sum of Binding Affinities of Small Molecules Identifies A Potent Inhibitor of SARS-CoV-2, MERS-CoV, and SARS Viral Proteases Validated by in Vitro Assays

Anushri Pal

Though the COVID-19 pandemic subsided, new variants appear, and no orally administrable prophylaxis monotherapies without side effects are available. Furthermore, climate change accelerates rates of disease emergence, so drug discovery and development must keep up with the pace. To hasten drug discovery efforts, computational screening must be used in new ways to reduce the number of false positive leads. With this aim, I blind docked many reported protease inhibitors on the SARS-CoV-2 Major protease to establish a relation between the binding affinity and IC50, which can be used to reveal new lead molecules. I found that the IC50s vary exponentially with the sum of the binding affinities of the 9 most stable protein-ligand complexes. Next, I performed blind docking of edited derivatives of the most active reported compound, and identified that the Bromo hydantoin derivative exhibited the lowest sum of binding affinities. This compound was then experimentally tested in vitro by NIH and found that it inhibited many variants of COVID-19 (EC50: < 10 nM and SI90 > 430 for B1.1.529 Omicron) [1]. This antiviral activity is comparable to or better than any drugs available on the market to treat COVID.

Reference:

[1] 2. A. Pal and M. D. Chordia, “Comparative in vitro antiviral evaluation of halogenated spiro-hydantoin isoquinolines: Identification of potent bromo compound against SARSCoV-2 protease”, ACS Spring 2024, March 17-21, New Orleans, Louisiana & Hybrid, March 17-21.

Keywords: SARS-CoV-2, Major protease, Binding affinity, EC50, IC50, SI-50, S-I 90, AutoDock Vina, Protein-ligand complex, Bromo Hydantoin derivative, Molecular docking, Major protease inhibitor

The Effect of Sugar on the Brain

Helen Li

Mia Dupee

Shreya Jha

Rationale: As high school students, we understand that most, if not all of us are constantly looking for ways to improve our test scores. Sugary foods are often deemed harmful to students, as teachers often advise against high amounts of sugar consumption before important exams. On the other hand, research shows that glucose levels in the brain connect to brain functions such as memory, critical thinking, and problem-solving. The brain uses half of all the sugar energy in the body because it is composed of many neurons, tissues, and cells. Therefore, cognitive functions including memory, thinking, and learning are closely connected to glucose levels. Looking further into the amount of glucose that creates the most efficient rate of synapses and overall function, there was a disparity in results across different research papers. Overall, there is no real underlying conclusion on the impact of sugar intake on the brain, with even fewer studies done on high school students and how sugar impacts their cognitive skills and education. We wanted to find the real impact sugar has on a high school student's cognitive function. We began this experiment to provide information to students to help guide their sugar intake before taking a test to improve their test scores.
Research question: Does sugar enhance cognitive functions such as critical thinking, problem-solving, and memory and recall in high school students?
Hypothesis: Sugar will enhance cognitive functions such as critical thinking, problem-solving, and memory and recall. The hypothesis is based on the rationale described above because it shows that sugar has a big impact on the brain and affects the brain's plasticity and ability to function.
Methods: First, participants arrived at the testing station on an empty stomach in the morning after waking up. The participants must be on an empty stomach because they must take the baseline test with the least amount of sugar in their system possible. We then evaluated how sugar affects the participant's cognitive function through three cognitive thinking tests. All three tests were in the same format of a digital Google Form, including three sections: problem-solving, critical thinking, and memory and recall. We created these tests by researching and compiling different test questions that tested each cognitive function. All three tests were timed. Participants are all high school students, their data is anonymous, and they were informed of their consent. Participants took the first cognitive test using a mobile device (the baseline test) without eating anything. Participants ate one-half of a Crunchy Nature Valley granola bar with 5.5 grams of sugar. After eating the bar, the participants waited ten minutes before taking the second cognitive test to let the sugar digest. After taking the second test, the participants ate the second half of the bar and waited another ten minutes before taking the final test.
Data Analysis: Statistical analysis and the R programming language were used to evaluate and look at the data and develop a visual representation of the data collected. We compiled the data into a data frame on Excel and imported that into R Studio. There, we were able to create three box and whiskers plots, 3 density plots, and perform Mann - Whitney "U" Tests and a Paired-T Test to analyze the significance of the data. On Google Sheets, we created scatter plots and regression lines to find the R^2 value.
Results: After conducting a trial with 30 participants, our data showed trends in each section that were tested; critical thinking, problem-solving, and memory and recall.
Critical Thinking: In the critical thinking section, the average score from the first test was 4 correct out of 5 questions. While on test two, it decreased to 2.8 out of 5, and further decreased on test three to 2.7. When the averages were plotted and a regression line was created, the R-squared value was 0.807. Since the R squared value is greater than 0.7, it indicates a strong correlation between the decreasing scores and increasing sugar intake.
Problem-solving: In the problem-solving section, the average score from the first and second tests was 3 correct out of 4 questions. On the third test, the average score decreased to 2.5 out of 4. When the averages were plotted and a line of best fit was created, the R-squared value was found to be 0.75, which indicates a strong correlation between decreasing scores and increasing sugar intake.
Memory and Recall: In the Memory and Recall section, there were three different questions, recalling a number, pictures from an image, and a list of words. On the first test, the average score was 5.6 out of 20, the second test averaged 7.3 out of 20, and on the third test had an average score of 10.3. When the averages were plotted and a line of best fit was created in Figure 3, the R squared value was found to be 0.975, denoting strong correlations between increasing sugar intake and increasing scores.
Overall: Overall, the average scores of the whole test increased from 12.6 to 14.3 to 15.5. After the average scores were plotted, they produced an R-squared value of 0.99.
Conclusion: Overall, our data suggests that our hypothesis is correct. However, when looking more closely, it can be seen that sugar decreases problem-solving and critical thinking skills, but improves memory and recall. The results of our experiment can be used to help high school students use sugar as a test-taking tool. Students should eat something containing sugar before taking a test that primarily involves memory retention and recall skills, such as a history, biology, or foreign language test. On the other hand, it can be advised for high school students not to eat foods containing large amounts of sugar before taking tests that involve critical thinking and problem-solving, such as a math or chemistry test.

Fight the Fibrosis: Investigating the role of a Epigenetic Regulator Protein X in Human Embryonic Kidney (HEK293) Cells in the Development of Kidney Fibrosis

Ayanna Rohil

Chronic kidney disease (CKD) affects 14% of the population in the USA. Fibrosis is the central pathway leading to CKD. The objective of this work was to determine the effects of Protein X, a transcriptional regulator in the BAF (Barrier-to-autointegration factor) chromatin, on kidney fibrosis using an in vitro disease model created by TGF-β and Cisplatin in HEK293 (human embryonic kidney) cells. TGF-β (fibrotic cytokine) and Cisplatin (DNA damaging agent for cellular injury)–induced profibrotic factor α-SMA (α-Smooth Muscle Actin) and DNA damage marker pH2AX (phospho-histone H2A.X). Consequently, to identify whether or not Protein X played a role in kidney fibrosis, the in vitro model was tested to compare the Protein X levels in naïve and treated HEK293 cells. The data identified a significant increase in the amount of Protein X in the profibrotic state induced by both TGF-β and Cisplatin, demonstrating that Protein X may play an essential role in the development of kidney fibrosis. The experiments were conducted using immunofluorescence techniques, and specific antibodies against α-SMA, pH2AX, and Protein X were used. All images were captured at constant intensity at 20x magnification. The fluorescence intensity of each image and the number of cells (using DAPI) were measured using the Image J software. The mean fluorescence intensity per cell was calculated to compare among groups, along with the Standard Error of the Mean (SEM). The enhanced levels of both α-SMA and pH2AX with TGF-β were reduced significantly by the siRNA-mediated knockdown of Protein X. Similarly, a statistically significant decrease in pH2AX expression was observed with the siRNA-mediated knockdown of Protein X in the Cisplatin-treated cells. This signifies that Protein X plays a crucial role in the expression of α-SMA and pH2AX in HEK293 cells, therefore impacting the development of cytokine or injury-mediated kidney fibrosis in an in vitro model system. The data collected in this experiment is promising to conclude that Protein X plays a significant role in kidney fibrosis and has the potential for treatments of kidney fibrosis in the future.

Effect of Long-Term Starvation on Oxidative Stress Tolerance

Jaeho Lee

This study explores the effects of different starvation diets on oxidative stress resistance in yeast , a model organism for human cancer. We compared short-term and long-term glucose starvation, as well as a novel starvation paradigm, and evaluated their impact on oxidative stress survival. An imaging-based spotting assay was used to determine viability post-treatment, and the appropriate statistical tests performed to ascertain effectiveness of each starvation condition . It was found that short-term starvation is effective, as a replication of previous experiments. Comparatively speaking, 14-day long-term starvation was less effective. But when multiple long-term paradigms were compared, 21-day seemed to be the most effective, indicating that longer starvation durations may represent an area for future explorations.

Alzheimer's in C. Elegans; Finding Efficient Supplements to Combat Symptoms of Alzheimer's

Alisha Raiker

Sneha Iyer

Soorya Soorej

Alzheimer’s disease (AD) pathogenesis is widely driven by the production and deposition of the β-amyloid peptide (Aβ). Aβ is derived from β-amyloid precursor protein (APP), a transmembrane glycoprotein essential in neural growth and repair. However, in a corrupted form, APP can destroy nerve cells and cause memory and cognitive function loss. Understanding the mechanisms by which APP operates is crucial for developing methods to mitigate cognitive decline in Alzheimer’s disease. Recent studies have shown that various supplements can enhance the nerve growth factor level, improving cognitive function in milder cases of AD. During the first stage of this experiment, we conducted a study using assay plates to test out which individual supplements would have the greatest positive effect on the aggregation of Abeta. In the second stage of this study, we will observe the effect of combining supplements from the first study in order to observe which combination establishes a greater effect on the C. Elegans. To observe the difference in the effect of the supplements on the worms, a chemotaxis index will be used on assay plates. The chemotaxis index calculates the movement of C. Elegans specifically toward a chemical relative to random movement. The more positive the index, the more worms move toward the attractant (diacetyl); the more negative the index, the more worms move away from the attractant (diacetyl) and toward the control side. We will then run a hypothesis test to see whether there is a statistical difference in the populations (control and treatment groups) that the samples were derived from. We will compare our calculated p values to a certain significance level in order to determine the correct hypothesis. This study aims to find the best suppressant to prevent the onset of Alzheimer’s or degeneration into worsening stages. These results can be used to create a concentrated diet for people who suffer from Alzheimer’s (or have genetic dispositions) using efficient, natural supplements that are accessible to the majority and mitigate against symptoms.

Protecting Our Moms: An Early and Effective Detection of Preeclampsia

Jahnavi Bolleddula

Preeclampsia is a condition during pregnancy that is characterized by hypertension and high levels of protein in the urine. Although the exact cause is not known, it primarily results from abnormal development of the placenta. In normal pregnancies, extravillous trophoblast cells invade deeply through the decidua and myometrium to infiltrate the maternal spiral arteries; this ensures that there is abundant blood flow at the maternal-fetal interface. However, in preeclampsia patients, the depth of trophoblast invasion is not aggressive enough resulting in insufficient remodeling of trophoblast cells , reducing blood flow. Preeclampsia affects 5-8% of pregnancies globally and is the cause of 16% of maternal death in the US. The incidence of this condition has been on the rise for the past 20 years. The only known cure for preeclampsia is delivery of the placenta. The literature strongly suggests that there are ethnic disparities in preeclampsia incidence. The goal of this project is to propose a prognostic biomarker screening test for early and effective detection of preeclampsia in pregnant women and identify biomarkers that can differentiate preeclampsia risk in different ethnicities . To accomplish this, the database NCBI was used to find differentially expressed genes in preeclampsia patients across different ethnic populations . These genes were first compiled into a spreadsheet, where there were around 1000 genes for the White population, 750 genes for the Black population, and 750 genes for the Asian population. Each dataset was imported into a functional analyzer called DAVID Bioinformatics Tool, where the gene list was narrowed by finding genes that were directly related to preeclampsia. These genes were then searched by Kegg Pathway analyzer and DAVID once again to discover the disease associations . Using an unpaired statistical T-test, statistically significant genes were identified. After a thorough literature search, the genes FLT1 and LEP for the White Population and FLT1, VEGFA, F5, and HLA-DQB1 for the Black population can serve as potential biomarkers that can be found in peripheral blood samples. In addition, after delivery, gene profiling of placental biopsies would be helpful to identify the potential risk of mothers for preeclampsia in subsequent pregnancies. Having a screening test for preeclampsia in each population will make the prognosis more objective and mitigate systemic inequality in maternal healthcare. The current analysis conducted in this project must be validated by using larger datasets when available.

Next-Generation Synthetic Receptor Circuits for T-Cell Therapy

Allison Liu

Chimeric antigen receptor (CAR) T-cell immunotherapy is a revolutionary form of cancer treatment in which T-cells are genetically reprogrammed to more effectively target tumor cells. Although CAR T-cell therapy excels against blood cancers, it struggles to eliminate solid tumors and relies on native T-cell response programs with limited customizability. Synthetic Notch (synNotch) receptors are engineered proteins that trigger gene expression upon binding a specific target protein (antigen). As an alternative to CARs, synNotch receptors enable the activation of custom genetic programs within engineered T-cells in response to user-defined tumor-specific antigen targets, expanding the efficacy and versatility of T-cell immunotherapy by enabling expression of non-native therapeutic payload genes. However, existing synNotch receptor circuits struggle to robustly express these custom genes and are prone to off-target gene expression (ligand-independent activation). In order to increase on-target gene expression and minimize ligand-independent activation, I redesigned a canonical synNotch receptor circuit (anti-CD19 VP64 + minCMV) by varying both the gene-activating domain of the receptor protein and the promoter sequence that initiates transcription of the nuclear reporter circuit. When co-cultured with CD19+ cancerous B-cells as model targets, the redesigned circuits demonstrated greater maximum on-target reporter gene expression than the canonical VP64 + minCMV design, with varying amounts of ligand-independent activation ranging from minimal to moderate. These enhanced synNotch circuits have the potential to help overcome challenges facing T-cell immunotherapy by providing greater control over tumor-specific non-native gene expression for cancer treatment.
Keywords: immuno-oncology, synthetic biology, cellular biology, cancer treatment, engineered T-cell immunotherapy, genetic circuits, synthetic Notch receptor protein

Autoimmune Diseases: The Impact of UV Radiation on the NLRP Gene

Adhvay Karthikeyan

One recently identified candidate that has been implicated in autoimmune response is the NLRP gene . NLRP is a crucial gene involved in the innate immune response, it codes for a protein that is associated with the regulation of inflammation. This gene plays the role of assembly in NLRP-family inflammasomes, which are multiprotein complexes that activate inflammatory pathways in response to cellular damage caused by stress or infection. This study explores the potential connection between UV exposure, NLRP inflammasome expression, and autoimmune disorders (e.g. Vitiligo, Rheumatoid arthritis, Psoriasis) through a systematic literature review by analyzing public datasets. By utilizing UV radiation data on skin cells, disease prevalence data, and NLRP inflammasome activity data this project aims to make a connection as to a factor of specific autoimmune disorders. This will be done by employing correlation and regression analyses. The underlying goal is to contribute valuable insights and highlight the need for further research to explore the underlying mechanisms for these diseases that don’t have a definitive cause. Ultimately, this work advances our understanding of the connection between UV exposure and NLRP-associated autoimmune diseases, potentially informing future preventive and therapeutic strategies.

Exploring Epigenetics: Effects of Environmental Stressors on C. elegans and the Evaluation of DNA Methylation in Mus Musculus via a Hybrid Deep Learning/Machine Learning Model

Aarushi Khatri

This project explores the influence of epigenetic modifications on stress susceptibility and susceptibility to disease in Caenorhabditis Elegans (C. elegans), employing an examination of variables such as movement, mortality rate, and health in response to stressors. The experimental design involves exposing wild-type and epigenetically modified C. Elegans to stressors, employing an eyelash stimulus as well as chemical stimuli such as pesticides, herbicides, and hydrocarbons. Following acclimatization and baseline measurements, the experimental results reveal that while wild-type C. Elegans exhibit varied stress responses, those with epigenetic tendencies consistently display heightened susceptibility. In response to the eyelash stimulus, the epigenetically modified group demonstrated increased reaction percentages and greater average movement. Additionally, the chemical stressors used were: a pesticide with DEET, an herbicide with an active ingredient of atrazine, an oil lubricant with hydrocarbons, glyphosate, a pesticide with an active ingredient of permethrin, and an herbicide with an active ingredient of vinclozolin. The results from the utilization of the chemical stressors showed that while both the wild-type and epigenetic-type of C. Elegans had reduced populations, the epigenetic-type worms had consistently higher mortality rates. In addition to the experimentation, this project uses publicly available datasets in a deep learning model to gain insights on stressors' effects on Mus Musculus. The deep learning model consists of both training the model on data, then testing it to predict the regions with DNA methylation in the DNA and chromosomes of the mice when the mice are treated with different stressors. In general, the findings suggest a correlation between epigenetic tendencies and increased stress susceptibility in C. elegans, emphasizing the significance of epigenetics in stress response mechanisms. Further data analysis and graphical representation can provide an enhanced understanding of these observed trends, and future research could explore the specific molecular mechanisms underlying stress susceptibility in epigenetically modified organisms, offering insights into potential therapeutic interventions.

Tick-Tock, Let's Reverse The Clock: A Systems Biology Approach to Unravel Neurodegeneration and Aging

Varun Nerella

Neurodegenerative diseases (NDDs) such as Alzheimer's Disease and Parkinson's Disease are primarily characterized by the presence of misfolded protein aggregates in the neurons. These NDDs have damaging effects on an individual and society, with no effective treatments to counter them.
What's more, as improvements in medicine have broadened the life expectancy of humans, prevalence of age-related NDDs have also increased significantly. According to a recent estimate, the United States government has over $600 billion annually in medical expenses and economic losses due to NDD.
(Neurodegenerative Disease Infographic: www.fightchronicdisease.org).

Are there specific age-related biological changes that may be exacerbated in neurodegenerative disease?
Literature review suggests that there are nine major hallmarks associated with aging (Cell 2013, PubMed ID: 23746838) and eight major hallmarks of neurodegenerative diseases (Cell 2023, PubMed ID: 36803602). In this research, primary focus was on mitochondrial and RNA binding proteins due to their links spanning multiple hallmarks covering both NDD and aging .

Analysis of publicly available aging datasets with human mitochondrial, and RNA binding proteins (RBP) subsets resulted in 89 unique mitochondrial and 38 unique RNA binding proteins that were altered.

Subsequent Protein-Protein Interaction (PPI) analysis of these unique proteins using data mining and Systems Network biology tools (StringDB and Metascape) revealed five smaller PPI subnetworks, with the dominant proteins being: ELAVL1, SLC25A5, PRKACA, GRSF1, and PNPT1.

Are these proteins relevant for neurodegeneration or are they random proteins caught up in the tangled networks?
Although studies show some linkage of these proteins in NDDs, it is important to understand the precise role of these proteins in the sub-clusters using experimentation in cell and animal models.

This study takes a novel approach to explore biological mechanisms in neurodegeneration by using systems biology and data-mining tools to analyze publicly available OMICs datasets. The preliminary data with enriched subnetworks and further literature review supports a connection between mitochondrial and RNA binding proteins in NDDs and aging .

These findings could be crucial for future research to help develop novel therapies, and biomarkers for NDDs using Network Medicine (Front Genet. 2019, PubMed ID: 31031797). Beyond combatting the social and individual impact of devastating NDDs, research in this field may help put one step forward to rewind the clock and promote healthy aging.

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Keywords: Neurodegenerative diseases (NDD), Alzheimer's disease, Parkinson's disease, Eight hallmarks of NDD, Nine hallmarks of Aging, Data mining, Public OMICs repositories and data analysis tools, human mitochondrial proteins, mitochondrial dysfunction, Reactive oxygen species (ROS), homeostasis, human RNA binding proteins, 3' UnTranslated Region (3' UTR), Loss of Proteostasis, Protein-Protein Interactions (PPI), Systems biology, StringDB, Metascape, Enrichment analysis, network clusters, PRKACA, SLC25A5, ELAVL1, GRSF1, PNPT1, Network Medicine.

Antibody Responses to COVID-19 and Influenza Vaccines Administered on the Same Day or Different Days

Susanna Barouch

The bivalent COVID-19 mRNA boosters became available in fall 2022 and were recommended alongside the seasonal influenza vaccine. However, the immunogenicity of concurrent versus separate administration of these vaccines remains unclear. In this study, I investigated the hypothesis that concurrent administration of these two vaccines would not impact immune responses to either vaccine. I performed a computational immunologic analysis of a database of antibody responses in healthcare workers who received the bivalent COVID-19 booster and the influenza vaccine on the same day or different days. IgG1 responses to SARS-CoV-2 Spike were higher at peak immunogenicity and at 6 months following concurrent administration compared with separate administration of the COVID-19 and influenza vaccines. These data show that concurrent administration of these vaccines yield higher and more durable SARS-CoV-2 antibody responses.

Drop the MYC: Synthetic Protein Design for Abrogating MYC Signaling

Arin Nazarian

The c-Myc protein, encoded by the MYC gene, is a transcription factor crucial for cell cycle progression, growth, and apoptosis regulation. Dysregulation or overexpression of c-Myc contributes to cancer development. This project aims to design synthetic proteins, anti-Myc1 and anti-Myc2, to induce ubiquitination-based degradation of oncogenic c-Myc, offering a potential approach to treat human cancers. AlphaFold Multimer was used to model protein interactions. Plasmid DNA containing the synthetic gene was isolated and purified. Human cell lines (HEK293 and A549) were used for transfection experiments. Plasmid cloning was performed and transfected cells were analyzed for gene expression and harvested for further analysis.

AlphaFold Multimer predicted accurate folding dynamics for synthetic Myc targeting proteins . Western Blot confirmed expression of synthetic Myc1 and Myc2 proteins. Confocal Imaging showed limited protein aggregation and expected nuclear localization. Proteostat indicated minimal protein misfolding. Proliferation assay demonstrated reduced proliferation of A549 lung cancer cells, suggesting effective degradation of native c-Myc signaling via ubiquitination. The project successfully designed synthetic proteins for targeted c-Myc degradation. Results from functional studies supported the effectiveness of the synthetic Myc inhibitors in reducing cancer cell proliferation . A limitation of the study was challenges with anti-Myc2 plasmid sequencing and production limitations for Myc2 impacting direct comparisons between Myc1 and Myc2. This work presents a promising strategy for targeting c-Myc in cancer cells through ubiquitination-induced degradation. The synthetic proteins designed show potential for further development as a therapeutic approach in cancer treatment.

Key words: c-Myc, Synthetic proteins, Ubiquitination Cancer treatment, AlphaFold Multimer

The Effect of Ocean Acidification on Seaweed Physiology

Gayatri Chaturvedi

Rising atmospheric carbon dioxide (CO_2) levels pose a pressing threat to global marine ecosystems through the process of ocean acidification. Seaweeds play a pivotal and multifaceted role in these ecosystems—not only as producers, but also as bioindicators and regulators of oceanic conditions. Studying their physiological changes in the presence of ocean acidification is therefore of critical importance. In this study, we investigate the response of three common New England seaweed species—Chondrus crispus, Ulva lactuca, and Sargassum natans—to variations in temperature and pH over a three-week period, focusing on daily percentage increase in wet weight, maximum photosynthetic yield, and total alkalinity of the colocated water as key indicators of health and adaptability. The ambient seawater and the particular values of temperature and pH values for each treatment are chosen so as to simulate ocean acidification. Measurements were taken weekly, using laboratory equipment such as a PAM fluorometer, wet weight scale, and alkalinity test kit. We find that results were highly dependent on species and varied across treatments. Such inconsistent effects not only suggest a diversity of outcomes, but also that certain species are better equipped to face and possibly mitigate the effects of an acidifying ocean .

Concentration-Dependent Efficacy of the Traditional Chinese Medicine Fructus Mume on the Inhibition of Escherichia coli K12 Growth

Weian Xue

Traditional Chinese medicine (TCM) is a form of alternative medicine that has been used for thousands of years in China and other Asian countries. Although its effectiveness is not well studied, it is still widely used in Asia and even Western countries today (Bruno 2020). One previous study shows that various types of TCMs have an inhibitory effect on gram-negative bacteria (Wong et al., 2010), which are generally harder to treat than gram-positive bacteria due to their dual membrane (Breijyeh et al., 2020). In this study, the TCM concentration dependent growth of the gram-negative bacterium Escherichia coli K12 (E. coli K12) in the presence of the TCM Fructus mume (F. mume), (otherwise known as wu mei or smoked plum) is measured. In order to do so, ultraviolet-visible (UV-vis) spectroscopy was used to measure the transmittance of samples, which were then used to form conclusions about the data. The results of this study showed that the higher the concentration of F. mume was, the higher the transmittance rate was. A higher concentration of F. mume was linked to less bacterial growth, and a lower concentration of F. mume was linked to more bacterial growth. The TCM F. mume has a strong inhibitory effect on E. coli K12 growth such that the higher the concentration of F. mume was, the more F. mume was able to inhibit E. coli K12 growth, and the lower the concentration of F. mume was, the less F. mume was able to inhibit E. coli K12 growth. Given that the IC50 of F. mume against E. coli K12 growth is very low, F. mume is able to effectively inhibit the gram-negative bacteria E. coli K12. In a real-life context, this study shows that TCMs like F. mume could serve as an alternative or supplement to antibiotics against gram-negative bacteria, which are usually harder to treat with antibiotics than gram-positive bacteria, especially when used in high concentrations.

A Novel Multivariate Framework for Precision-Driven Oncogenic Pathway Disruption and Targeted Therapeutics Innovation

Mary Deng

Cancer remains the second-leading cause of death worldwide. Despite acute clinical needs, status quo treatment modalities still include a combination of highly toxic chemotherapy and radiotherapy. Oncological drug discovery is both costly and prone to failure. Emerging evidence indicates that the ability of cancer cells to rapidly proliferate and resist treatment is due to their reactivation of certain transcription factors and signaling pathways typically upregulated during embryogenesis but downregulated in adult tissues, a phenomenon termed oncofetal reprogramming. This research seeks to identify novel nontoxic anticancer therapies through a unique approach. RNA-seq gene expression data of three primary unisex cancer types derived from the same embryonic layer, the endoderm, were obtained from CCLE: head neck squamous cell carcinoma of larynx or hypopharynx, lung squamous cell carcinoma; and esophagus squamous cell carcinoma. Endoderm non-cancerous lung epithelial cells were used as controls. Differential expression gene (DEG) analysis was conducted, along with the Benjamin-Hochberg procedure in R. The DEGs were cross-compared to identify the shared genes across all three analyses, which were hypothesized to be oncofetal reprogramming genes. Kaplan-Meier survival analyses were conducted using real patient clinical data to assess the prognostic relevance of the top genes, such as NAT14, which is associated with worse patient survival for endoderm cancers ($p<0.00001$), but better patient survival for mesoderm cancers ($p<0.001$). Gene Set Enrichment Analysis was performed using DAVID validating shared genes overlapped with developmental functional pathways (FDR q-value <0.005), thus supporting my hypothesis. 14 inhibitors ($q<0.05$) that target tumors by modulating the oncofetal reprogramming genes in cancer cells to those in normal cells using CMap. A multiplexed high-throughput viability screening assessed cytotoxicity and evaluated drug molecular mechanisms. Esomeprazole was found effective at killing cancerous but not normal cells ($p<0.005$), while statins serve as a proof of concept. The top shared genes (e.g., PPP1R35, NAT14, RNF126, CBX8) are novel targets for therapeutic development and can be used as novel biomarkers for patient prognosis. Future research will expand this application to cancers of other developmental origins and test synergy with other treatment modalities.

Keywords: life science; biomedical research; genetics; technology innovation; computational framework; public health; biomarker; early diagnosis and detection; patient well-being; diagnostic and predictive tool; mutations; cancer therapy; patient survival; treatment outcome; tumor development and progression; embryonic development

Using Lysins as an Addendum to Antibiotics for Staphylococcus Epidermidis Biofilm Eradication Via Targeting Biofilm Matrices

Alisha Kamara

Amir Rodrigues-Carbajal

The formation of biofilms, syntrophic communities of microorganisms, are particularly problematic due to their ability to resist antibiotics. In hospital settings, the formation of biofilms, usually on indwelling devices, allows for pathogenic bacteria to flourish, as the matrix of the biofilm serves as a defense mechanism. Due to the increasingly resistant extracellular matrix of biofilms, antibiotic therapy is becoming less and less successful. To combat this issue, we used Lysostaphin, an antibacterial enzyme that has the ability to cleave the peptidoglycan layer of the cell wall of Staphylococcus species. We aimed to demonstrate that when used in conjunction with antibiotics, the effectiveness of bacteria eradication increases. From the Staphylococcus species we selected Staphylococcus epidermidis, as it is the most common biofilm found on indwelling devices. To conduct this, we had spread S. epidermidis on some agar plates divided into three equal sections. We then placed one antibiotic disk in each section, which contained Oxacillin, Vancomycin, Tetracycline. These antibiotics are most effective for treating S. epidermidis, however, we had also used Ciproflaxacin and Amoxicillin. We had also plated these antibiotics on S. epidermidis with the lysostaphin. To ensure maximum accuracy, we plated S. epidermidis with lysostaphin alone. Each agar plate was then placed in an incubator at 37° Celsius, which is considered optimal temperature, for 24 hours. Using calipers, we measured the zone of inhibition of each disc to test if the use of lysostaphin and antibiotics together, or the use of the lysostaphin alone, is successful as an antistaphylococcal therapeutic method.

Can the Bacteriophage Virus Successfully Eliminate E. Coli Bacterial Cultures?

Ian Schneider

Isabella Murdzia

Leo Bulatewicz

A group of students had conducted an experiment in which they examined the effectiveness of phage therapy through an experiment utilizing various dilutions of T4 bacteriophages against E. coli bacteria within a closed environment. This experiment had been based upon the growing prominence of phage therapy, a type of treatment that uses bacteriophages as a method to combat strains of antibiotic resistant bacterial infections. The treatment had been tested and used several times in cases where it had been successful, although the method has only recently been introduced. In order to determine whether the phages were effective, the notion that a greater concentration of phages would be able to kill more bacteria had been suggested, as their concentration would likely affect their performance against bacteria. As the amount (or dilution) of T4 bacteriophages was altered within the experiment, the number of E. coli bacteria remaining would change as a result. Several variables would have to be kept constant in order to obtain accurate results, including the type and amount of materials used and the environment everything was stored in. Three iterations of the experiment had been conducted in order to ensure the accuracy of the results. Within all three iterations, the control plate, which contained no bacteriophages, had contained the most E. coli bacteria, while the dilution containing the greatest amount of bacteriophages had the least amount of bacteria remaining. The data reinforced the initial hypothesis that a greater number of bacteriophages would kill more bacteria and suggested that with further testing, phage therapy may someday become a successful form of treatment.

Utilizing the Kirby-Bauer Test To Ascertain the Effectiveness of Standard Healthcare Antibiotics for Respiratory Infections

Milana Camilleri

This experiment strives to apply the disk diffusion test to determine which antibiotic best eliminates K-12 Escheria coli, replicating its strength against respiratory-targeting bacteria (Streptococcus pneumoniae, Haemophilus, influenzae, and Morxella catarrhalis). Following the COVID-19 pandemic, there has been an evident rise in hospitality and mortality rates due to respiratory infections. A selection of 4 of the most used antibiotics to treat these infections will be tested: amoxicillin, penicillin, erythromycin, and sulfamethoxazole. It was hypothesized that the most commonly used antibiotics, penicillin and amoxicillin, will be the most effective.

The concentrated disks of these antibiotics will be tested in a method called a disk diffusion test , which will then be measured via zone of inhibition when combating the K-12 E.Coli. This project's findings have the potential to contribute to medical lab research on how to best combat these infections and observe antimicrobial susceptibility.

Sulfamethoxazole (4.5904 mm killed in average) demonstrated the greatest strength against K-12 E.Coli, followed by Amoxicillin (2.8892 mm on average) Erythromycin (1.8204 mm), then Penicillin (1.1348 mm).

The hypothesis was rejected, however the purpose of this experience was still fulfilled. Applying the more effective sulfamethoxazole in hospitals and clinics may serve as an alternative for patients as they contract COVID-19, and thus become more successive to respiratory infections. Moving forward, accessibility is a large factor that can be well-integrated into this experiment. With a measure of cost/mg, this design can determine an antibiotic with both cost- efficiency and strength against bacteria in mind.

Solving Our Planet's Plastic Problem: Developing a Biological System That Turns Toxic Waste Into Drinkable Water and Fertilizer

Elizabeth Hanechak

Plastic pollution is an environmental emergency. Since 1950, over 8.3 billion metric tons of plastic waste has been generated (Asad, 2018). It is estimated that between 75 and 199 million tons of plastic waste is currently in the ocean (Wakefield, 2018). Previous research sought to increase the catalytic power of cutinase through the deletion of a disulfide bridge within the native cutinase structure. Through site-directed mutagenesis, the disulfide bridge at C31-C109 was deleted. This mutation, C31S, was shown to have degraded the PET into its component monomers, the organic compounds ethylene glycol and terephthalic acid (Sethi et al., 2011; Sulaiman et al., 2012). Ethylene glycol (EG) and terephthalic acid (TPA) are both toxic organic compounds. Therefore, following exposure of PET to C31S and PET's subsequent degradation, there must be another step developed in order to prevent a rise in the amount of organic pollutants in the environment. This research utilized the application of a microalgal-bacterial consortium of C. protothecoides and P. putida to the treatment of the ethylene glycol and terephthalic acid which remain after PET is degraded by the C31S enzyme. C. protothecoides was chosen as the microalgae for its ability to live off of glycols and other organic compounds (Kishi et al., 2015; Kishi et al., 2018). P. putida was chosen as the bacteria due to its highly varied metabolism and its previously proven tendency to engage in symbiotic relationships with microalgae from the Chlorella family. First, samples containing ethylene glycol and terephthalic acid in their pure forms were prepared and exposed to this consortium for 48 hours, and it was found that the consortium caused a major decrease, 30-50%, in the concentration of these organic compounds. Because of the promising results shown by the consortium and its remediation of the pure compounds, the consortium was then prepared again and exposed to the compounds produced by plastic degradation. These tests repeatedly showed that the compounds had been completely remediated by the consortium. Microalgal biomass was harvested from these samples, as the C. protothecoides creates biomass after digesting the organic compounds and living off the carbon. This biomass can be converted into highly nutritious fertilizer, while the reaction broth was filtered through a modified countertop reverse osmosis filter and was found to be fully potable. In total, when combining each part of this research, the final result is a biological system that can convert plastic waste into drinkable water and fertilizing material, while also being carbon sequestering due to this specific algae's high carbon needs and being extremely sustainable, as the growth process for all three microbes does not require a high amount of energy and all are very robust.

Three-Pronged Approach to Investigating the Development of Novel Inhibitors Targeting KRAS G12C in Lung Cancer.

Yiming Ding

KRAS is a transmembrane glycoprotein that leads to cancer once mutated. Once mutated, it turns from a GDP-bound inactive state to a GTP-bound active state, which turns on downstream signaling pathways and regulates cell growth, division, and proliferation. There is an urgent need for reliable and effective drugs to treat cancer, and recent studies have discovered an allosteric binding site close to the GDP site of the G12C mutation. However, data has shown that drug resistance has been developing in lung cancer patients treated with drugs targeting the KRAS G12C mutation. Also, Chinese herbal medicine, though undocumented and experimentally tested, has therapeutic effects and great potential in the treatment of cancer. We used a three-pronged approach to find components of Chinese herbal medicine that are effective in the inhibition of KRAS G12C and to understand the process of drug development. We collaborated with the Shokat lab from the University of San Diego and found that Molecule 1 has minimal toxicity on non-mutant KRAS cell lines and has slight inhibitory effects on KRAS G12C cell lines. performed molecular docking for virtual drug screening, recombinant protein expression and analysis for drug analysis, and single-cell RNA Sequencing for the understanding of drug insensitivity. We We identified potential inhibitory small molecules for KRAS G12Ci treatment and validated our predictions with experiments. Our study offers new insights into the mechanisms underlying KRAS G12C inhibition and provides a promising avenue for future drug development efforts.

Key Words: Lung Cancer, Novel Targeted Drugs, Chinese Herbal Medicine, Virtual Screening, Recombinant Protein Expression, Single Cell RNA Sequencing

The Effects of Vaping on the Inflammatory State of Macrophages in the Context of Infection.

Linah Lasri

Rahil Kistas

Victoria Boguslavskaya

In this experiment, the topic “The Effects of Vitamin E Acetate (VEA) in Vapes and E-Cigarettes on Macrophage Function Through the Study of TNFα” was investigated. With the rise in the usage of vapes and e-cigarettes, the rates of pulmonary illnesses like EVALI (e-cigarette and vape-associated lung injury) have also increased. While VEA has been suspected of causing EVALI, there has not been enough data to confirm this hypothesis. There have also not been enough studies to research the effects of VEA on the immune function of the lungs. The hypothesis is if the macrophages are treated with VEA and then infected with SP3, then the TNFα levels will increase because the VEA harms the macrophages.

The purpose of this experiment is to investigate how VEA affects the rapid response cytokine TNF α levels in the presence of Streptococcus pneumoniae 3 (SP3). The results of this research will help expand the known effects of VEA and EVALI.

RAW 264.7 murine macrophages were plated into a 12-well plate with the following 4 experimental groups: no VEA and no SP3, no VEA with SP3, with VEA and no SP3, with VEA with SP3. The plate was then treated with 25μM VEA for 30 minutes, infected with SP3 (MOI 10) for 1 hour in their respective wells, and treated with gentamicin after two hours. RNA was isolated using the Norgen Biotech single cell RNA purification kit (CAT #51800), and RNA yields were measured using nanodrop. Reverse transcription was performed using the Invitrogen superscript II kit with random primers (CAT #18064-022), and q-PCR was performed. CT, ΔCT, and ΔΔCT values were measured. An ANOVA and a multiple comparisons test were conducted.

The ΔΔCT were as follows: -VEA -SP3 R1: 1.005, -VEA -SP3 R21:1.694, -VEA +SP3 R1:13.51, -VEA +SP3 R2: 21.51, +VEA -SP3 R1: 1.365, -VEA -SP3 R2: 5.032, +VEA +SP3 R1: 12.79, +VEA +SP3 R2: 25.95. The ANOVA p-value was 0.0227. The multiple comparisons test p-values were as follows: -VEA -SP3 and -VEA +SP3: 0.0339, -VEA +SP3 and +VEA +SP3: 0.999, -VEA -SP3 and +VEA -SP3: 0.651. It was determined that VEA has no statistically significant effects on the TNFα levels when the macrophages were infected with SP3.

Prediction Model of Diabetes Complications Based on Genetic Engineering Improved Genetic Algorithm Optimized BP Neural Network

Xingchi He

Nowadays, with the rapid development of science and technology, people's living standards have been greatly improved, and many chronic diseases have also been brought, including diabetes. The occurrence of diabetes not only poses a serious threat to human body, but also poses a threat to human life with its development. BP (Back Propagation) neural network model can well solve the logic regression problem of single factor and multiple factors, and also better solve the collinearity problem of multiple factors. BP neural network optimized based on improved genetic algorithm can reflect the influence mode and degree of various factors, and can be predicted from the perspective of patients' diet, exercise, and doctors' application of insulin. In this paper, the patients in a hospital were taken as the research object, and the BP neural network method was used to analyze the causes of the disease. The prediction model was used to screen out the high-risk groups of diabetes patients and reduce their incidence rate. Secondly, according to the collected data, the relationship between diabetes related complications was analyzed in depth by using genetic engineering technology, thus providing a theoretical basis for the prevention and treatment of diabetes and its complications. The prediction accuracy of BP neural network optimized by genetic algorithm can reach 94.1%. In the high-risk group of diabetes, taking appropriate diet and behavioral measures can reduce the probability of diabetes. The prediction scheme of diabetes complications proposed in this paper is simple and its cost is low, which can greatly reduce the cost of prevention and treatment of diabetes and the probability of diabetes.
Keywords: Diabetes Complications, BP Neural Network, Genetic Engineering, Improved Genetic Algorithm.

Temperature’s Effect on the DNA Clarity in Gel Electrophoresis

Madison Laster

This project is about how different temperatures will affect the clarity in gel electrophoresis. How a person would do this by extracting DNA from a strawberry by storing the extracted DNA at -20□, 4□, 22□, and 37□, and wait 1 week. Then a person would place the DNA in a gel electrophoresis machine to get their results. They would see that warmer temperatures show the best results. So why does this matter? This matters because it can show greater results when scientists use gel electrophoresis to identify the DNA found in crimes. Also genetic counselors can get better results when storing DNA. Instead of the colder temperatures they should store it at room or warm temperatures. This information is also useful to researchers. When the DNA is needed to be stored for an extended period of time scientists know what temperature is best for DNA and data analysis.

A Novel Deep Learning Pipeline to Noninvasively Detect and Treat Gynecologic Diseases Using MiRNA Expression and In Silico Modeling

Palak Yadav

Women’s health is a growing crisis as 1 out of 10 women will experience chronic gynecological diseases, yet treatment can be delayed up to 4-11 years, due to the social stigma, ambiguous symptoms, complex pathology, and a lack of noninvasive and accessible diagnostic tools. MicroRNAs (non-coding RNA segments) offer promise for improved health outcomes as they regulate gene expression and are easily detectable in bodily fluids. This study aims to create a novel deep-learning pipeline that utilizes blood miRNA expression levels and clinical data for early disease detection and effective treatment . Several machine-learning models were trained on patient datasets to predict 5 gynecologic conditions (endometriosis, PCOS, and breast, ovarian, and endometrial cancer). The models performed with greater than 90% for binary classification and 82% for multi-disease classification. Feature extraction techniques were applied to identify biomarkers and perform pathway analysis and gene clustering to better understand the unique and shared pathology behind malignant and cancerous female conditions. Furthermore, the pipeline integrates differentially expressed genes, protein network analysis, and oncology platforms to establish a miRNA-centric drug discovery framework to provide optimal treatment options and identify therapeutic targets for future studies. Notably, miR-let-7 d emerged as a consistently dysregulated miRNA targeting the RAS signaling pathway, offering drug targets to limit chemoresistance and monitor disease progression . Overall, this model aims to improve health outcomes for female patients by reducing misdiagnosis and waiting periods, creating avenues for accessible and noninvasive serum-based diagnostics, assessing treatment options, and identifying targets for future personalized therapeutics.

Examining Enhanced Komagataeibacter hansenii Production via Unconventional Food Waste

Anika Karre

Bacterial cellulose is a biomaterial whose various structural properties allow for versatility in its designs and worldly applications in the medical, food, and cosmetics fields. This project focused on a commonly used cellulose producing strain, Komagataeibacter hansenii. High cost is the key drawback regarding how this species of bacteria is typically grown, particularly when translating this process to larger scale production. The cost of the culture medium itself can account for approximately 30% of the production cost. This project focused on further building on past research by identifying how replacing the typically used culture medium, Hestrin-Schramm, with an alternative food waste source, would affect the growth and production of Komagataeibacter hansenii. Preliminary testing utilized pineapple juice as a culture medium to simulate replacing the HS medium and how it would impact the yield. The juice was sterilized, combined with inoculum in six-well plates, and after resting in the incubator, an 83.27% increase was observed in cellulose yield from the Hestrin-Schramm medium to the pineapple juice medium. From there, leftover mango peels were used as a food waste culture medium and underwent an XRD analysis to compare its crystallinity patterns with the HS media cellulose. The results shed light on the efficacy of using mango peels as a successful culture medium replacement as the peaks on the graph were similar in both samples. Further testing needs to be initiated to observe how other properties are affected by this change, particularly ones that affect its biomedical applications.

Multi-Omics Analysis of Pancreatic Ductal Adenocarcinoma Reveals New Insights Into the Tumor Microenvironment

Evan Li

Pancreatic ductal adenocarcinoma (PDAC) is an extremely lethal cancer that accounts for over 90% of all pancreatic cancer cases. With a 5-year survival rate of only 12%, PDAC has proven to be extremely chemo-resilient, desmoplastic, and immunosuppressive to most current therapies, including chemotherapy and surgical resection. In recent years, focus has shifted to understanding the tumor microenvironment (TME) around PDAC, enabling a greater understanding of biological pathways that can ultimately lead to potential for future drug targets. In this study, we leverage a combination of single-cell and spatial transcriptomics to further identify cell populations and interactions within the highly heterogeneous TME . We demonstrate that SPP1+APOE+ tumor-associated macrophages (TAM) exhibit a synergistic pro-fibrosis correlation with CTHRC1+GREM1+ cancer-associated fibroblasts (CAF), leading to extracellular matrix (ECM) production and a worse prognosis. Our results highlight the crosstalk between stromal and myeloid cells as a significant area of study to target the ECM in future therapeutic strategies.

Investigating Genetic Variability in Amyotrophic Lateral Sclerosis to Identify Patient-Specific Treatment with Antioxidants

Kruthi Gundu

Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease (NDD) that can lead to death within 30 months of diagnosis in 1 in 2 patients. There are many cellular and genetic mechanisms that can cause ALS in a particular patient. Due to this variation in disease pathways and linked genes, combined with a significant lack of research and treatments specific to ALS risk factors and pathways, current ALS treatment models are inefficient. This project focuses on antioxidants, which have been widely studied and used to treat NDDs due to their ability to minimize damage caused by Reactive Oxygen Species. Antioxidants, specifically Vitamin E, have been researched as a therapy for ALS in the past. However, their connection to specific ALS-linked risk factors and pathways has been minimally researched. It was hypothesized that if Vitamin E was used to treat ALS models representing different genetic risk factors, then there would be different levels of improvement in symptoms. Using Caenorhabditis elegans to model ALS mutations, the genes SOD1, C9ORF72, FUS, UNC13A, FUS, and SQSTM1 were tested. Chemotaxis assays and Worm Tracking assays were used to measure nerve damage. It was identified that Vitamin E was able to restore chemosensing in SOD1, but not in other mutant models C9ORF72, FUS, UNC13A, FUS, and SQSTM1 (p-value < 0.0001 for all findings). To best treat ALS patients in the future, it is crucial to focus on patient-specific risk factors and pathway destruction causing ALS symptoms rather than the symptoms themselves, otherwise ALS patients may not receive the most beneficial medication and positive prognosis.

Utilizing Methotrexate and Dimethyl fumarate on the STING Pathway Modulation to alleviate symptoms of Crohn's disease.

Shaurya Patni

Autoimmune diseases, impacting 10% of the population, lead to self-attacking immune responses, causing inflammation. Crohn’s disease, characterized by gastrointestinal inflammation, results in nutrient malabsorption, diarrhea, ulcers, and pain, often treated with immunosuppressive drugs that heighten infection risks. The inflammation creates opportunities for activating the STING pathway. The STING pathway exacerbates the situation by releasing pro-inflammatory chemokines and cytokines in the digestive system, causing further damage. This research evaluates Dimethyl fumarate (DMF) and Methotrexate (MTX) for inhibiting the cGAS-STING pathway, aiming for treatments with fewer side effects. Utilizing bone marrow-derived macrophages (BMDM) stimulated by diABZI, the study employed ELISA and rt-qPCR to measure the impact on pro-inflammatory markers like CXCL10, IL-6, TNFa, and IFNb, which were chosen as they are all essential markers of Crohn’s. Results indicated DMF and MTX significantly reduce inflammation, with DMF notably inhibiting the STING pathway at a transcriptional level, while MTX showed protein-level inhibition. This suggests a promising direction for Crohn’s disease management, offering more specific and less harmful treatments. The findings underscore the necessity for improved therapeutic approaches in the escalating global incidence of autoimmune diseases, emphasizing DMF and MTX's potential in providing targeted relief and minimizing existing treatments' immunosuppressive drawbacks. The study's insights mark significant strides in autoimmune research, advocating a nuanced treatment model and setting the stage for subsequent investigations into side effects, immunogenicity, and combined medication efficacy.
Keywords: Inflammation, Tissue Cultures, Targeted Therapies, Immunocompromised, Crohn’s Disease, STING pathway

Screening Compounds Targeting Optic Nerve Regeneration Through Epigenetics

Carey Huang

The optic nerve, consisting of millions of retinal ganglion cells (RGCs), is an integral part of the central nervous system (CNS). It is responsible for transmitting visual signals from the retina to the brain and damage to this neural pathway can result in conditions such as glaucoma (Yohannan et al. 2017) or optic nerve atrophy, eventually leading to vision loss. A distinguishing feature of the mammalian CNS is its pronounced regenerative capacity during embryonic development, which sharply declines in postnatal stages (Varadarajan et al. 2021). This contrast in regenerative capabilities between embryonic and mature tissues indicates the presence of regulatory mechanisms such as epigenetic factor (Yun 2015). Epigenetics involves heritable changes in gene function that occur without alterations to the DNA sequence itself , through DNA methylation, histone modifications, and the action of non-coding RNA molecules (Goldberg et al. 2007). These changes are key to cellular diversity (Huang et al. 2019), homeostasis (Wagner et al. 2021), and the body's developmental processes (Skinner 2011), with the ability to adapt gene expression in response to environmental stimuli. Notably, factors such as histone deacetylases (HDACs), DNA methyltransferases (DNMTs), ten eleven translocation (TET) proteins, and histone acetyltransferases (HATs) are recently been identified as playing an important in the CNS for the development, protection, and potential regeneration of the optic nerve. (source A; source B; source C) However, with epigenetics still a relatively new field of research, many of its effects on optic nerve and RGC regeneration remain under-researched and hold promise for future discoveries.

A2. Importance

Retinal Degenerative diseases and injuries impact millions of people; around 80 million people worldwide suffer from Glaucoma alone, a figure expected to rise to 111 million by 2040 (Tham et al. 2014). By advancing our understanding of retinal regeneration through epigenetics, this research could pave the way for novel treatments, potentially restoring vision and improving the quality of life for countless individuals.

A Novel In vitro Co-culture System of Primary Human Adipocytes and Primary Murine Cortical Neurons

Aanya Gupta

Communication between the nervous system and adipose tissue is crucial for regulating food intake and maintaining metabolic health. Dysfunctional communication can lead to metabolic diseases such as diabetes and neurological disorders like Alzheimer's disease. However, studying this interaction in vitro is challenging due to the lack of suitable models that replicate the complexity of the in vivo environment.

This project aimed to establish an optimized in vitro direct co-culture system using primary human adipocytes and primary murine cortical neurons. Initially, compatibility tests were conducted by culturing neurons in adipocyte media and adipocytes in neuronal media. Results showed that while neurons in adipocyte media led to overgrowth of epithelial cells, adipocytes in neuronal media retained their cellular identity, as confirmed by adipocyte marker gene expression via qPCR, despite minor morphological differences. Further tests revealed that the morphological differences were due to a missing component in the neuronal supplement.

Furthermore, research indicated that the differentiation cocktail given to adipocytes is harmful for neurons. Thus, stimulated adipocytes were replated on top of neurons. Differentiation after replating was optimized by stimulating pre-adipocytes for 3 days before replating on day 5 to balance stress impacts and differentiation efficiency.

Considering the results of these tests, a co-culture system was established and evaluated through staining with adipocyte and neuronal markers. In the end, this optimized model provides a valuable platform for studying neuro-adipose communication and its implications in metabolic and neurological disorders, filling a critical gap in existing research.

Early Detection of Lung Cancer through miR-155 via Surface Enhanced Raman Spectroscopy (SERS)

Christina Quin

Lung cancer remains the leading cause of cancer-associated deaths globally. Early detection is pivotal for improving patient outcomes, yet current diagnostic methods like CT scans and sputum cytology are limited by high false-positive rates. This study explores the utilization of miR-155, a microRNA associated with lung cancer, as a novel biomarker for early detection in conjunction with Surface Enhanced Raman Spectroscopy (SERS). Utilizing silver nanoparticles to enhance the detection sensitivity of miR-155, this research presents a non-invasive, accurate, and cost-effective method for early lung cancer diagnosis. Through meticulous experimental design and analysis, this study demonstrates the potential of SERS combined with miR-155 as a powerful diagnostic tool, offering the possibility of improving early detection rates and thereby patient survival rates significantly.

Ancestral Microbiota and Associated Microbial Metabolites Effect on Gut Health During Recovery of Anorexia Nervosa

Katelyn Yang

28.8 million, or about 1 in 10 Americans, will suffer from an eating disorder (ED) in their lifetime. Yet EDs are under-researched and under-treated. In 2023, overall ED research funding amounted to $58 million, less than 5% of total mental illnesses funding. There is a critical need for research and advance our understanding of EDs, given their severity and increasing prevalence. The aim of this investigation determines whether ancestral gut microbiota with a great fiber-fermenting capacity will positively influence the gut microbiome of individuals with Anorexia nervosa (AN). In order to prove that Ancestral gut microbiota and High Fat High Fiber diet had a positive impact on gut health, the model organism used were 16 C57B/6J mice. The mice were given High Fat or High Fat Fiber diets and were also given the Ancestral gut microbiota or Western gut microbiota. The Activity Based Anorexia (ABA) model was the used to “induce” AN for the first 14 days and the mice were orally gavaged with microbiota for 7 days after the model. Throughout the experiment, weight recovery was recorded, as well as stress response and voluntary wheel running. Looking at the results, the group given Ancestral Gut Microbiota while on the High Fat High Fiber diet gained the most amount of weight during weight recovery while the High Fat High Fiber diet group with the Industrialized gut microbiota actually lost the most amount of weight. This means that diet is necessary in order to see the effect of the gut microbiota. The open field stress response test showed that Mice that were given ancestral gut microbiota moved significantly more compared to the mice given industrialized gut microbiota post treatment potentially suggesting that the ancestral gut microbiota plays a role in physical activity and overall movement. The voluntary wheel running High Fat and Industrialized Microbiota group had significantly ran more compared to the other group and mice that were given ancestral microbiota while already on a High Fat High Fiber diet ran more towards the end of the experiment. From the results, the data above supports the hypothesis and shows that High Fat High Fiber diets with Ancestral Gut Microbiota make the ideal treatment for ED recovery.

Determining the effects of TGF-β1 on COL1A1 Expression in Hepatocellular Carcinoma

Charuvi Singh

Hepatocellular Carcinoma (HCC), a major subset of liver cancer, stands as a global health concern, accounting for over 700,000 annual deaths. Current treatments offer limited efficacy, leading to persistent complications and tumor recurrence. A deeper comprehension of novel targets against HCC progression is imperative due to ineffective clinical treatments . Many cell signaling transduction pathways have been identified and correlated to excess Collagen I production, which is an indicator of HCC progression. However, the involvement of Transforming Growth Factor-β1 (TGF-β1), which plays an important role in HCC development, and the gene encoding Collagen I (COL1A1) in HCC remains unclear. This study aims to elucidate the previously unknown relationship of the TGF β pathway and the COL1A1 gene in HCC by testing how TGF-β1 regulates the expression level of COL1A1 and its impact on the proliferation and migration of hepatocellular carcinoma cells. After HepG2 cells were confluent, COL1A1 was knocked down via siRNA transfection to assess changes in viability and migration rates of HCC, in vitro through a MTT and wound healing assay, respectively. These cells were then treated with TGF-β1 and COL1A1 levels were assessed. Based on the findings, COL1A1 is overexpressed in HCC. Upregulation of COL1A1 facilitates the proliferation and migration of HCC cells through the TGF β pathway. The correlation of TGF-β1 and COL1A1 upregulation introduces a novel therapeutic target against HCC, deterring HCC cell progression by reducing ambient levels of collagen I in the carcinoma tissue.
Key Words: COL1A1, Hepatocellular carcinoma, Collagen I, TGF-β1

Modulation of Cellular Senescence by Short-Chain Fatty Acids

Yulin Zheng

Aging, as the major risk factor for a variety of diseases, has an urgent need to understand its complex mechanisms. Cellular senescence, marked by irreversible growth cessation, plays a substantial role in aging and related conditions. Notably, short-chain fatty acids (SCFAs), resulting from the fermentation of dietary fibers by gut microbiota, are associated with this process. Numerous studies have elucidated the beneficial role played by SCFAs in regulating metabolism and ameliorating inflammatory processes. However, despite these insights, the intricate impact of short-chain fatty acids on the aging process remains obscure. In this study, we try to scrutinize the influence of SCFAs—acetate, propionate, and butyrate—on cellular senescence using MRC-5 human lung fibroblasts. By evaluating cell proliferation, beta galactosidase activity, senescence-associated markers (p16 and p21), and key transcription factors (p53 and NF-κB), we will figure out the effect of individual fatty acid on cell senescence. These findings will shed light on the complex roles SCFAs play in the aging paradigm and emphasize their potential role as modulators of cellular senescence. Understanding their impacts may pave the way for targeted interventions to address aging-related challenges and promote healthier aging trajectories.
Keywords: aging, cell senescence, short-chain fatty acids, proliferation

Supporting Kidney Tubule Growth on 3D Printed Scaffolding

Beckett Wainner

Mackenzie Keenan

Many third-world countries lack access to state-of-the-art medical advancements due to limited money. For example, specialized health care with replacement organs that are bio-printed with the patient's cells. This technique would drastically reduce the risk of rejection and could potentially eliminate the waitlist for donors. However, this process can get expensive. Even starting in the lab where these cells would grow, materials such as 12mm glass coverslips for mammalian cell culture can cost upwards of $50.00 each. While that might not seem like much, remember that price is for one 12mm piece of glass that can only hold so many cells. Once materials such as serum, trypsin, microscopes, CO_2, incubators, sterile biosafety cabinets, etc., are added, the price skyrockets quickly. With the hopes of reducing this price to expand access to the less fortunate around the world, we 3D printed plastic coverslips, which would cost less than $0.50 each, that perform with the same quality as their traditional glass counterparts. We expect that this product will aid in the advancement of state-of-the-art techniques, especially for those who would not be able to afford it otherwise.

Genetically Engineering Microorganisms and Biomanufacturing Enzyme Products

Oliver Lorenz

Rose Cohen

Bio-manufacturing is key to producing lifesaving medicine. Amino acids, vaccines, cytokines, fusion proteins, growth factors, biopharmaceuticals and monoclonal antibodies all utilize biomanufactured products. One of the most common types of bio-manufactured medicines is enzymes. Lactase, or Beta-galactosidase (β-Gal), is an enzymatic protein that breaks down lactose into its subunit's galactose and glucose, allowing for easier digestion of these monosaccharides. Bio-manufacturing medicines using plasmids allows for easier upscaling of enzyme production. We hypothesized the use of E. coli that lacks the ability to create lactase to test for efficacy of recombinant DNA techniques. We will introduce pBLU® plasmids expressing GLB1 and ampicillin resistance to alactasial E. coli, demonstrating organism transformation and mimicking the manufacturing process pharmaceutical companies use to produce lactase. The E. coli will be grown inside of 500ml spinner flasks and then continuously stirred tank bioreactors to upscale the process. We also are researching a plasmid vector to demonstrate the purification process using chromatography columns that will bind to a polyhistidine tag (His6 tag) on the β-Gal N and C termini. In the process of organism transformation, we take the gene GLB1 and introduce the DNA to plasmid vectors. The recombinant plasmids are then put into an organism that can be easily upscaled, like yeast or E. coli, where the gene will be expressed, and lactase will be produced. Manufacturing companies will use massive bioreactors with thousand-liter capacities to grow the transformed organism and then harvest, purify, and supply the produced lactase, insulin, or other desired molecule. Insulin-producing companies have used E. coli and Saccharomyces cerevisiae (brewer’s yeast) to produce their product. We will be using alactasial E. coli to model the process of organism transformation. We also aim to demonstrate the purification process that all companies follow to turn their harvested product into drugs fit for human use. If we can take parts of manufacturing from some organisms and put them in others, then we can increase our production of life-saving medicines.

Seagrass Wasting Disease’s Effect On Eelgrass Under Environmental Stressors Such As Salinity

Christian Bunge

Finn Yemini

Maxwell Fernald

Due to its alteration of oceanic conditions, climate change is expected to heavily contribute to the decline of the coastal ecosystem. Zostera marina (common eelgrass) is among the plants that may be vulnerable to such changes. The protist Labyrinthula zosterae (seagrass wasting disease or SWD) is an antagonist towards eelgrass, and also may be affected by changes in oceanic climates. Rapid loss of eelgrass has been observed multiple times, with a 90% population decline throughout the Atlantic in 1930 due to infection by seagrass wasting disease. More recently and more locally, the Duxbury, Plymouth, and Kingston Bays have all observed severe eelgrass loss. Within the Cohasset and Scituate harbors, even more rapid loss had occurred, with almost all eelgrass in these two harbors dying within a two-year interval. Though studies have been conducted into the effect of environmental stressors on seagrass wasting disease , there exists very little recent literature or analysis of this phenomenon in the Eastern Atlantic region . This study investigates the effects of the growth of Labyrinthula zosterae on eelgrass under the environmental stressor of salinity through a cross infection experiment. Artificial infection was achieved through two novel methods, and analysis of infection was measured by lesion coverage, both by human and pixel analysis. Other factors, such as the change in the number of leaves and the total area of the plant were measured before and after the treatment of varied salinity and SWD. Analysis of data demonstrated a low positive correlation between salinity and seagrass wasting disease with little significance. Although this conclusion is compatible with previous literature, there are also many limits to this data set, and further research on this topic is encouraged.

The Effect of Sunscreens on the Mortality Rate of Daphnia magna

Erin Bourque

Regan Montague

The effects of sunscreen on coral reefs and other saltwater settings are abundantly researched , while the effects of sunscreen on freshwater environments are unclear due to a lack of research. The ingredients in many sunscreens harm freshwater ecosystems, and sunscreens that claim to be “reef friendly” to saltwater environments often have similar formulas to those which do not claim to be “reef friendly”. Daphnia magna are crucial components of freshwater ecosystems and food chains. The mortality rates of Daphnia depend on the type of sunscreen that they are exposed to, and this experiment tested whether spray or lotion formulas were more deadly to Daphnia, and whether sunscreen claiming to be “reef friendly” caused more fatalities than sunscreen that did not claim it was “reef friendly” in freshwater ecosystems. Through the pilot and full experiment, we found that sunscreen kills more Daphnia than the control, however lotion had a much higher mortality rate than the spray sunscreen. We also discovered that, despite Coral Isles’ claim to be “reef-friendly”, both brands had a similar effect. Overall, the experimental groups with sunscreen had higher mortality rates than the control groups, just as we predicted. However, the results did not fully support our original hypothesis because the brand of sunscreen did not affect the mortality rate. With this knowledge, next time you find yourself swimming in a lake or pond, try using sun protective clothing such as a rash guard instead of sunscreen to save your skin and practice sustainability.

Examining the Effects of Synthesized Fertilizer for Sustainable Hydroponics

Ben Juo

Neal Tandon

Seiji Ting

Hydroponics is a compact, sustainable, and fast way to grow crops; however, it is underutilized in developing countries and urban areas partly due to resource deficiency. The objective of our project was to create a scalable, reliable, and inexpensive hydroponics module, and to test it with control and experimental liquid fertilizers. Each module consists of two PVC pipes with 4 holes each, connected in a U-shape. They rest on two 5-gallon buckets, and a fish pump circulates liquid through them. Each day, plants were measured, leaves were counted, and pH, humidity, and temperature were logged. Serial dilutions of the solutions were performed later to test for the presence of microorganisms. The test groups were water, industrial fertilizer, homemade fertilizer (boiled and filtered vegetable waste), and 50/50 homemade and industrial fertilizer. Over two and a half weeks, the industrial fertilizer performed best based on leaf count and size, closely followed by water, then the 50/50 and homemade fertilizers. This project supports that an inexpensive and effective hydroponics setup is feasible, and industrial fertilizer is not required, therefore making it possible in resource-deficient areas. Since industrial fertilizer performed only marginally better than water, it can be concluded that the prototype can adequately grow lettuce with water alone, making it extremely accessible and sustainable. Future projects include in-depth nutrient analysis, different ratios of nutrients in the homemade fertilizer, and running the experiment for longer to examine the fertilizers' long-term impact on growth.

How Does Microgravity Affect Seed Growth?

Tram Pham

Understanding how seeds grow in a microgravity environment and their anatomy reaction to this change is important because this can help scientists figure out how to grow plants when they go to space. In addition, this research can expand the current knowledge of plant development on Earth compared to space, potentially leading to new agricultural practices.

If a seed is being grown in a microgravity environment, then the length of the seed growth will decrease compared to seeds grown in a gravity environment.

The Effect of a Nitric Oxide-Rich Diet on C. Elegans' Locomotion Under Heat Stress: a Path to a Model System for Nitric Oxide-Mediated Cancer Signaling Pathways

Leah Koutal

Previous studies have identified a connection between B. Subtilis and thermotolerance in C. elegans linked to the presence of nitric oxide (NO), a signaling molecule that initiates the HSF-1/DAF-16 pathways required for maintaining homeostasis under stress. In addition, NO and nitric oxide synthase (NOS) activity has been shown to be involved in tumor cell development. Their role is paradoxical, and based on concentration and environment, NO can have both genotoxic and angiogenic properties towards tumor cells. C. Elegans' phenotypic response to elevated temperature on the NO-rich diet of B. Subtilis could be used as a model system to further study how DAF-16/HSF-1 pathways are related to tumor cell growth via the presence of NO. There is limited research on the impacts of bacterial diet and heat stress on locomotion patterns in C. elegans. The purpose of this preliminary research was to investigate how bacterial diet modulates C. elegans' locomotion patterns (number of omega-turns per minute) under elevated temperatures of 25°C. It was hypothesized that on a bacterial diet of B. Subtilis, C. elegans would be better equipped to maintain their frequency of omega turns at an elevated temperature compared to an E. Coli diet. C. elegans' omega turns were recorded on plates cultured with B. Subtilis or E. Coli after a 3 hour exposure and 24 hour exposure at a control temperature of 18.8°C and an experimental temperature of 25°C. On an E. Coli diet, C. elegans exhibited reduced frequency of omega turns at 25°C compared to the 18.8°C control while on a B. Subtilis diet, at 25°C nematodes maintained their frequency of omega turns compared to the 18.8°C control. Taken together, the results suggest B. Subtilis plays a role in regulating nematode thermotolerance. These results can potentially be explained by the function of nitric oxide, which is most applicable to transcriptomic changes under short-term heat shock. This study has broader implications for cancer cell research considering nitric oxide's ubiquitous role in cell signaling. The effect of nitric oxide variation could be studied in C. elegans, which share elements of the HSF-1/DAF-16 pathways with humans, to more clearly portray the causal relationship between in vivo NO concentration, microenvironment, and tumor cell development.

A Study on the Effect of Caffeine on the Growth and Development of Zebrafish Embryos Using Automated Quantitative Assessment of Morphological Changes

Anika Jacob

Caffeine is a common pollutant within freshwater systems due to its abundance in the environment. Caffeine residue enters the water primarily through wastewater excretion, especially in areas where there are not adequate water filtration systems ("Occurrence of caffeine in the freshwater environment: Implications for ecopharmacovigilance", 2020). Zebrafish are freshwater organisms that have potential exposure to lethal caffeine concentrations. It was hypothesized that exposure to caffeine would negatively affect the development of zebrafish embryos, as they progressed from an embryo to larvae and the growth of zebrafish embryos in specific anatomical structures. 80 embryos were divided into four groups containing no caffeine, 0.18 mg, 1.8 mg, and 18 mg/10 ml of caffeine. They were imaged for six days and their eye size and yolk size were measured using the software FishInspector. The number of embryos alive and dead and the number of embryos and larvae within each group were recorded each day. There was a statistically significant difference in the average eye size between the four groups. On day four, there was a statistically significant difference in eye size and yolk sac size between the four groups. Chi-square tests revealed that there was a statistically significant difference in the development of embryos and larvae in each of the four groups on Day Three. The embryos in the 18 mg group died at a much faster rate in comparison to the control group. These results support the hypotheses that caffeine exposure affects the growth and development of zebrafish embryos.

Space Food: Hydroponic System Adapted for Growing Microgreens in Space

Lily Swilling

Access to renewable food sources is a vital aspect of any journey to space. Most astroagriculture studies focus on successfully growing crops in either regolith (dirt found on the surface of the moon) or in a hydroponic system. Few studies have considered the seed efficiency (ratio of edible plant to seed weight) and caloric efficiency (ratio of total calories grown to seed weight). Due to weight restrictions aboard a spacecraft, the seed efficiency and caloric efficiency are critical considerations in evaluating food resources in space.

The present study identified the microgreens that perform best in a hydroponic system adapted for growing plants in space. The study evaluated the seed efficiency and caloric efficiency for each crop. The study also experimented with various growing techniques for reducing the presence of mold, which is a common challenge in hydroponic systems.

Six different types of microgreens were grown in a deep-water culture (DWC) hydroponic system: alfalfa, broccoli greens, buckwheat, green lentils, mung beans and red clover. Each DWC system included an air stone attached to an air pump in order to improve air circulation to the root systems. During days 1-4, the seeds underwent a soak/rinse process to encourage germination. On day 5, the seeds were transferred to an individual DWC system. Grow lights were applied on day 9, when small leaves began to emerge. Lights were scheduled on a 12-hour light and 12-hour darkness cycle in order to balance photosynthesis with cellular respiration.

Due to the presence of mold in the first round of experimentation, the experiment was repeated a second time. Distilled white vinegar was introduced into the water mister during the germination as a method for combating the mold.

Broccoli outperformed the other crops in seed efficiency with a ratio of 13.32 in Group 1 and 8.68 in Group 2. Buckwheat produced the lowest seed efficiency in both rounds of experimentation with a seed efficiency of 3.09 and 3.43, respectively.

Green lentils performed the best in caloric efficiency with a ratio of 5.81 and 4.90, respectively. Despite the low seed efficiency of buckwheat, the high caloric content of this crop resulted in a favorable calorie efficiency of 2.85 and 3.17, respectively. The higher seed weight of mung bean resulted in the low caloric efficiency in both rounds, thus suggesting that it would not be a good candidate as a space crop.

Mold was prevalent on the green lentil crops in both rounds of experimentation. The white distilled vinegar had no impact on mold control, and resulted in additional mold to appear on buckwheat, alfalfa, and mung bean during the second round of experimentation.

Overall, larger seeds, such as green lentil and mung bean, experienced better growth results than the smaller seeds, such as red clover and alfalfa. A likely explanation is that the larger seed size provided the plant with a greater nutrient reserve. The larger sized seeds also were easier to spread evenly on the DWC hydroponic trays, which may have resulted in less overcrowding. We conclude that green lentils, buckwheat and broccoli are important microgreens to evaluate as potential food sources in space.

Future experimentation is necessary to explore alternative solutions for combating mold, such as adding a fan to provide better air circulation or reducing the watering schedule. A comparison study evaluating growth of the same crop in regolith and a hydroponic system would provide additional insight in determining the best crop for astroagriculture.

The Effect of Organic Compost vs Non-Organic Compost on Phaseolus Lunatus Growth

Aarya Atale

Around the globe, there is a growing focus on health, sparking discussions about organic versus non-organic produce. The price disparity between organic and non-organic foods, with organic options being approximately 21% pricier, raises concerns, particularly for families with limited budgets. This prompts scrutiny of the actual nutritional disparities between the two. Conventional use of nitrogen fertilizers in non-organic farming has led to perceptions of lower health benefits compared to organic alternatives. Recent research is delving into the effects of heightened nitrogen levels in non-organic produce, exploring potential health risks such as cancer. This study aims to compare the impact of organic and non-organic compost on plant growth, leaf characteristics, and the levels of phosphorus, nitrogen, and potassium in the soil resulting from compost application.

Affect of pH Value in Soil on Flowering Plant Growth

Madhu Hasini Nagunoori

The basis of this experiment is to analyze the effect of soil pH on plant growth and bloom color , using the perennials bulbous flower, paperwhites, that grow in only 3 - 4 weeks. This study is performed because a plant's life, which consists of health, growth, and reproduction, is dependent on very precise environmental conditions. These include sunlight, nutrients provided, amount of water, temperature, space, etc. Many of these factors have been examined and are still continued to be examined for many years by scientists. The optimal conditions or conditions at which proper and healthy plant growth occurs has been known to people in general who are interested in gardening, even if they do not have much knowledge about this in science. However, pH value is not as well known as some of the other factors listed and what amounts of them are appropriate for plant growth. The pH of soil is just as important as other environmental factors because the pH of the soil determines what kinds of nutrients such aluminum, magnesium and iron are available in soil and how mobile or able to move and interact with others are. If the pH of soil is different or improper for the growth of a certain kind of plant , then either sufficient amounts of one or more particular nutrients are not available or there is too much of one or more kinds of nutrients . Too low amounts of specific nutrients are bad because it means that there are not enough chemicals or substances to react with other materials and somehow result in something that aids in the health and maturing of plants. Too high amounts of specific nutrients are also bad because too high levels of these chemicals can be toxic or poisonous to the plant that it may kill it due to some sort of intense sensory or chemical activity triggered by these molecules. So, through this experiment, it is wanted to know what is the optimal pH for plant growth or particularly paperwhites. Next, the color of flowers based on pH was the second study. This is because in hydrangeas, the color of their bloom is blue under acidic conditions, pink or even reddish in basic conditions, and purple when the pH changes. This is through a certain pigment called delphinidin, a type of anthocyanin, that is capable of interacting with aluminum ions provided in acidic pH soils. The delphinidin pigment has another structure within it, called a red flavylium cation, that gives the natural red color but produces the purple to blue quinoidal base anion upon loss of more hydrogen protons, rearrangement of double bonds, and interaction with aluminum ions. Thus in acidic pHs where more aluminum ions are available, react with a delphinidin molecule to produce the blue color, while in basic conditions, in the lack or scarcity of the aluminum ions, the delphinidin pigments expresses the red color from the flavylium cation and producing a pink color to the human eye by mixing with the white color of the hydrangea sepals. So, through this experiment, it is wanted to know if such a mechanism can be seen in other kinds of plants as well if they are provided with certain conditions.

In terms of the experiment itself, 10 paperwhites were first grown in 10 uniform containers where almost ¾ of the bulb were inside regular all purpose organic soil, and watered when needed. The ten plants were divided into two equal groups where the first group is used to study plant growth and each one was labeled either 5.5, 6.0, 7.0, 7.5, and 8.5, while the second group is used to study flower bloom color and was labeled the same way as the first group but also with delphinidin. After about two and a half weeks, each of the plants started to be watered with 100 milliliters of their respective solution, three times a week. These solutions were made by using citric acid to reduce the pH and baking soda to increase the pH using a pH probe to measure the pH, and maqui berry extract to replace delphinidin as it includes delphinidin within it as well. At the end of every week, measurements of the first group were taken such as height of the highest sprout from a single plant, average height of all the sprouts, length of the longest leaf, value of the largest flower diameter, average flower diameter of all flowers, and other extra visual observations. For the second group, only the flower color was noted (if there were any flowers) along with the extra visual observations.

After the experiment occurred, results show that the plant watered with a pH of 6.0, had the highest value of 378.6% in length of longest leaf, the plant watered with a pH of 7.0 had highest values of 430% in diameter of the largest flower of the plant and 397% in average flower diameter, and the plant watered with a pH of 7.5 had the highest values of 351.2% in height of the tallest stem of the plant and 305.5% in average stem height. This shows that paperwhite plants grow the best in around neutral conditions of 7.0 - 7.5 due to the particular nutrients that are more available in this pH range. However, the only exception may be that the longest leaf was from the plant watered with 6.0 pH solution, but this might only be an error or accident that might have occurred in this test, or potentially certain nutrients were available at this pH that promotes leaf growth. Additionally, in the second group that was watered with delphinidin along with different pHs , showed that the plants watered with delphinidin and the pHs, 5.5, 7.0, and 7.5 were the only ones with flowers from the second group and were of the color white. From this, it was concluded that in this particular test, the pH had no effect on the color of the flower as they all were white and not blue or pink. This might be because there were some experimental errors that were not controlled in this study due to lack of equipment and time. These are more deeply identified and explained in the Experimental Errors and Future Improvements sections.

Gravitropism in Microgravity: Simulating the Effects of Constant Rotation on Plant Germination using Arduino Clinostat

Shuting Zhu

In this research project, we investigated plant growth in microgravity-like conditions using a clinostat to understand how plants respond to reduced gravitational stress. Plants depend on gravity to orient themselves towards the source of light during their early stages of growth, stimulating a negative gravitropic response called gravitropism. To do this, we subjected plants to two different experimental conditions; one where the plant was placed on a clinostat and the other was simply subjected to earth's gravity. NASA is already doing this in space, but doing this on Earth would be far cheaper and it would be a way to predict the plants' behavior in space. We hypothesized the seeds that are being planted in the clinostat will potentially have a lower growth rate than the seeds being planted at the normal gravitational level due to altered root orientation and nutrient uptake. This is because plants rely on gravity to aim their roots downward toward where all the nutrients are. This behavior helps roots penetrate deeper into the soil, increasing their chances of encountering and absorbing water and nutrients essential for the plant's growth and development. However, due to plants being placed in a microgravity environment for this experiment, this indirectly influences nutrient uptake by impacting root growth and orientation in the soil which can impact the growth speed. The independent variable consists of seeds being grown in a microgravity environment and seeds subjected to the earth's gravity, while the dependent variable is the growth rate, and the control is the seed placed in a condition subjected to the earth's gravity. To do this, we can build a simple clinostat using Arduino, rotate the seed constantly, and then use a ruler to record the growth length of the two conditions over time. The materials we need are 3D printed PLA blocks to use as base and support for the Petri dishes, Arduino, servo motor to rotate, cress seeds, and Petri dishes. To collect data, we can have a control seed in a non-spinning setting and one in the clinostat and compare their changes through a period of 3-4 days. Both of the experimental groups were able to germinate with different trends. Results showed faster and more consistent growth in the clinostat group, aligning with a 90-degree germination angle indicative of altered root gravitropism. Dehydration-induced size reduction in both groups suggested a universal stress response in plants. The experiment revealed that seeds in the clinostat group exhibited faster and more consistent growth over three days compared to the control group, potentially influenced by reduced gravitational stress. My findings hint at a potential link between microgravity and enhanced plant development, offering insights for space agriculture applications.

Tiny Heroes of Resilience: Revealing Tardigrade Tolerance to High Glucose for Innovative Diabetes Treatments

Olivia Chen

Tardigrades, eight-legged small invertebrates, have been shown to survive extreme conditions, such as freezing temperatures, by entering an inactive state called cryptobiosis. In this project, I tested the hypothesis that tardigrades can survive a high glucose environment, and the higher the concentration of glucose and the more exposure time duration, the more tardigrades enter the status of cryptobiosis and remain alive. If tardigrades demonstrate resilience in high concentrations of glucose, it suggests the existence of certain molecular mechanisms within these organisms that could play a crucial role in enhancing glucose tolerance. For my experiment, tardigrades were put into three different concentrations of glucose: 0 mM (no glucose), 15 mM (high glucose), and 30 mM (extremely high glucose). Each sample was analyzed for 1, 2, 3, and 7 days of exposure to the conditions by counting the number of tardigrades in active and inactive statuses in five fields on 20X magnification under a microscope. At the end of each exposure period, the tardigrades were transferred into clean culture dishes with only spring water to examine their recovery to active status in the following days. Throughout the exposure stage, the 0 mM group maintained above about 85% active tardigrades. However, the 15 mM and 30 mM groups experienced a significant decline in active status. Analysis using a Mixed Effects Model revealed that both glucose exposure time ($p = 0.0007$) and glucose concentration ($p < 0.0001$), as well as the interaction of time and concentration ($p < 0.0001$), significantly impacted the active status of tardigrades. Upon transfer to normal living conditions without high glucose exposure, tardigrades became active. This recovery from an inactive to an active state suggested that tardigrades underwent cryptobiosis and successfully survived high glucose challenges. Data analysis using a 2- way ANOVA test followed by Tukey’s pairwise comparison tests revealed that the viable tardigrades decreased by 10% in the 0 mM group (control group), 12% in the 15 mM group, and 17% in the 30 mM glucose group. The viability of tardigrades after high glucose exposure was not significantly different from the control (0 mM glucose) group ($p > 0.05$). In conclusion, exposure to high glucose induces cryptobiosis in active tardigrades in a dose- and exposure-time-dependent fashion. High concentrations of glucose exposure do not significantly impact tardigrades' survival. Further studies of the molecular mechanisms that underlie tardigrade tolerance to high glucose exposure could offer innovative strategies for addressing diabetes in humans .
Key Words: glucose tolerance, tardigrades, cryptobiosis.

Sustainable Salads for Small Spaces: The Comparison of Lactuca sativa Growth Between Traditional Farming and Aeroponic Growing

Teagan Chisholm-Godshalk

Aeroponics are known for their benefits of being able to be compactly produced and can grow anytime throughout the year. This project asks the question, will the harvest of the aeroponics successfully match or outgrow traditional farming? This study is crucial because it proves you can grow your own produce within a living space, so people can recycle used up items and grow multiple kinds of vegetables or fruits.

The aeroponics was built by watching a simple Youtube video and consists of items like a 17 gallon tote, PVC pipes, a pond pump etc…The traditional methods were built by paint containers, potting soil, earthworm castings and many other supplies listed on the board. Six aeroponics and six controls were all placed under an LED light for 18 hours a day, helping all the plants to get sufficient lighting in winter.

It was hypothesized “If lettuce is grown aeroponically, then the growth of the lettuce will match or surpass the traditional farming method because aeroponics is a more productive growing method”. This hypothesis was proven incorrect. This experiment ended with the traditional method being in the lead. Comparing the graph at the end, the average of the traditional method had surpassed the average of the aeroponic method.

In conclusion, based on the results, aeroponics grows slower than the traditional method. Fast growing plants are essential; growing radishes would have been a benefit because of how fast they can grow. This experiment adds to the research already known because these aeroponics were grown in November-January, which is the off season. This research differs from past studies because both plants are grown in a house, not in a greenhouse or lab.

Generational Effects of Human Stressors and Pollutants on Wildlife Modelled by Drosophila Melanogaster

Melissa Panaligan

Zayaan Mamun

Our experiment tested whether Drosophila flies exhibited stress that affects their offspring and deviates from their normal evolutionary behavior when exposed to light, air, or noise pollution. We transferred ten flies into each tube, with three tubes each in four different conditions: control conditions, under a lamp, next to a radio that played constant noise, and one that we engulfed in smoke regularly. We monitored these flies in their conditions with the goal of reproduction. No offspring were recorded yet, however, the plan is to put the offspring in different control tubes and monitor discrepancies in behavior compared to the behavior of the parent flies. We'll record how many times they reproduce, and compare it with our control. To check for relative stress levels, we wall followed the flies to check for centrophobism. We placed the flies from each tube into petri dishes and recorded them for one minute, taking note of whether they were inside the inner ring, the middle ring, or the outer ring closest to the wall at set intervals. Flies that spent the majority of the time closest to the walls were more centrophobic, as centrophobism in flies is a clear indicator of stress. All flies exhibited stressed behavior, but our noise flies were the most centrophobic, with the biggest number of flies recorded near the walls. Noise was the factor that induced the most anxiety in flies and they exhibited odd behavior. Pollution from the environment has a significant effect on organisms' normal behavior.

Ashwagandha's Effect on Locomotion in a C. elegans Model of Huntington's Disease

Sarah Mattson

Huntington’s Disease (HD) is a progressive neurodegenerative disease that causes a range of motor, cognitive, and behavioral symptoms. In the United States, 30,000 people are diagnosed with HD. Another 200,000 are at risk of developing the condition. There is currently no cure for HD. Chorea is one of the outward physical symptoms of HD. Research studies show that oxidative stress is correlated to and possibly a cause of Chorea. Antioxidants such as ashwagandha have been found to reduce oxidative stress and, therefore, could potentially limit motor symptoms. In this experiment, an HD model of C. elegans that expresses 128 polyQ was used to model HD in humans. This study measured the motility of the C. elegans through a thrashing assay in M9 buffer. 4 groups of C. elegans were tested: N-2 wild-type C. elegans given 0.1% DMSO, EAK 103 C. elegans given 0.1% DMSO, and EAK103 C. elegans given 25µL and 5µL concentrations of ashwagandha. Following experimentation and data collection, preliminary results from this study suggest that ashwagandha reduces locomotive symptoms in a C. elegans HD model.

Comparing the Effects of BPA and BPS on the Heart Rate and Reproduction of □□□□□□□ □□□□□

Sierra Kelch

Bisphenol A (BPA), a chemical used in hard plastics for food containers, is an endocrine disruptor with negative cardiovascular and reproductive effects. When this was discovered, manufacturers switched to using Bisphenol S (BPS) to make their products “BPA free”. This study aims to test the effects of BPA and BPS on heart rate and reproduction to determine if they have similar effects.

It was hypothesized that as concentrations of BPA and BPS increase, heart rate and reproduction would decrease because this effect was observed in previous studies at high BPA concentrations. It was further hypothesized that BPA and BPS would have similar effects due to their similar structures. Daphnia magna were exposed to either BPA or BPS at concentration levels found in humans. After six days, their heart rate and egg count were measured.

As hypothesized, BPA and BPS had similar effects on D. magna physiology, suggesting BPS may be just as harmful as BPA. These concentrations of BPA and BPS had no effect on reproduction, although this result was inconclusive due to high variability. In contrast, both BPA and BPS caused an increase in heart rate, counter to the first hypothesis. The hyperbolic curve shape suggests this result may be caused by BPA and BPS binding to a receptor, and possibly different receptors at different concentrations, with each receptor leading to a different effect on heart rate. These new hypotheses could be tested by using selective inhibitors of endocrine receptors and a broader concentration range of BPA and BPS.

Keywords:
Environmental; Cardiovascular; Reproduction; Plastics; Public Health; Product Safety

The Intergenerational Effect of Ethanol on the Cognition and Behavior of D. melanogaster

Jocelyn MacDonough

Alcohol can have serious cognitive and behavioral effects as well as being able to affect the epigenome . It is also thought that these effects may be sexually dimorphic. This project's purpose was to determine the intergenerational effects of alcohol on the cognition and behavior of D. melanogaster and how these effects are influenced by sex. Their learning, memory, and behavior were tested.

There were two diets: a 5% ethanol diet and a control diet. There were 13 groups. Two were the control male and female, two were the alcohol male and female, six were the first generation offspring, and three were the second generation offspring. All offspring groups were reared on the control diet. Learning and memory were tested using a negative reinforcement assay, and behavior was tested using a geotaxis assay.

It was found that D. melanogaster on an alcohol diet had significantly worse learning, memory, and behavior compared to the control groups. However, females on an alcohol diet had worse learning and behavior compared to the males. The first and second generation offspring had significantly worse learning and memory compared to the control group . While the first generation had worse behavior, the second generation did not. Offspring of male and female flies on an alcohol diet had worse learning and better behavior compared to offspring of just one alcoholic parent , suggesting that there are differences in offspring based upon the sex of the parent that consumed alcohol. Further research includes testing further generations and using different alcohol concentrations.

The Antiviral Effects of Melatonin-Producing Plant Growth Promoting Rhizobacteria

Elyse McManus

In the last two years, the number of individuals suffering from malnourishment worldwide has increased by an estimated 150 million people. This increase can be largely attributed to the increase in climate change-induced stressors on plants. In addition to exposing plants to increased abiotic stressors, such as temperature and flooding, climate change conditions increase plants' susceptibility to pathogens and contaminants. Extensive research has indicated that melatonin has the ability to reduce the impact of these increased stressors on plant growth, both biotic and abiotic. Additionally, Pseudomonas Fluorescens, a bacteria that produces hormones and molecules to promote plant growth, has the ability to produce melatonin molecules. Therefore, this study aimed to measure the impact of the application of tryptophan, a melatonin precursor, in combination with Pseudomonas Fluorescens, on tomato plant growth and resistance to Tomato Mosaic Virus, a common plant pathogen. The growth and melatonin concentration of plants with this treatment was compared with that of plants treated only with Tryptophan, only with Pseudomonas Fluorescens, only with melatonin, a group treated with Pseudomonas Fluorescens and melatonin, and a group with no treatment. The findings indicate that the exogenous application of melatonin can have a positive impact on the growth of plants, but that melatonin-producing Pseudomonas bacteria are more effective at increasing plant growth and combating a biotic stressor. However, errors such as small sample sizes, poor environment, sample variations, plant dehydration, and a destroyed ELISA kit impacted the test results of this project. For future experimentation, multiple melatonin concentration measurements will be taken to reduce random differences, and a new ELISA kit with a linear standard curve should be utilized.

Microalgae: Nature's Solution to Oil Pollution

Ekaavli Daga

Around half of the world’s oil supply is transported via ocean and over 700 million gallons of oil pollute the ocean annually. This oil kills marine life, destroys coastal habitats, and creates “dead zones,” which remain toxic for decades. Current methods of oil remediation are inefficient, expensive and detrimental to the environment. They are also ineffective at treating emulsified oil, which is even more toxic. This project sought to explore a cost-effective and environmentally-friendly solution to this problem by using Scenedesmus quadricauda, Nannochloropsis oculata, and Chlorella vulgaris microalgae. It was hypothesized that these microalgae strains would remove over 50% of motor oil from an emulsion, with C. vulgaris being the most effective.

Bioremediation rates of S. quadricauda, N. oculata, and C. vulgaris were recorded in a 2% motor oil emulsion, relative to a control without microalgae. Every other day for 9 days, two samples from each group were centrifuged and measured for oil concentration by pipetting out the oil phase from the water.

C. vulgaris reduced the oil concentration by over 75% during the experimental period, and T-tests showed that this change was significant compared to the control. However, S. quadricauda and N. oculata did not significantly reduce the oil. Possible explanations for these results could be attributed to differences in microalgae (phagotrophic versus osmotrophic) or hydrocarbon type in the motor oil emulsion. Future work would seek to increase measurement accuracy, study effectiveness of microalgae by oil type, and explore how lipids could be harnessed from the microalgae after bioremediation.

Comparison of Pest Resistance in Crops with Natural and Artificial Priming

Steven Xiang

Insects are well known for being pests that ravage crops. Oftentimes they are the root cause of food insecurity, leading to starvation and economic burden, and currently widespread methods of defense are harmful to consumers. Plants have developed various defense mechanisms against them that are triggered in different ways . Unfortunately, the defenses only become active hours after damage occurs, which is often too late due to the rapid rate at which insects consume tissue. Conventional pest remedies involve pesticides that are highly toxic and cause health detriments in humans.

However, by knowing which triggers best activate the defense mechanism against insects, farmers will be able to protect their crops by utilizing those triggers as primers, or vaccines for plants. This study aimed to test various priming methods on plants to find their effectiveness in triggering plant defenses to prevent insect herbivory using a tomato and tomato hornworm model. The project involved four experimental groups that each utilized a different defense priming method , which included a previous insect exposure group, mechanical damage group, saliva damage group, and silicon supplement group. Here, prior insect exposure is natural priming, whereas the rest is artificial priming. Both positive and negative control groups are included. After a priming period, plants will be exposed to direct insect herbivory. The primary goal of this project is to find the primer that best activates a plant's defense system in preparation for insects . The effectiveness of plant defense is assessed through mass analysis of the insects used for herbivory, and chemical analysis of the levels of two major defensive enzymes. The primer that leads to the best defense against herbivory will be the one used for the plant group with the least mass gain in its insects and the most expression of enzymes. By analyzing the data, I have found that the insect group and spit group are equally effective in preventing herbivory when compared to the control group . All other treatment groups show no significant effects.

In conclusion, my study indicates that previous insect exposure and spit exposure are both effective primers for plants to gain immunity against insect pests, therefore uncovering a potential path for future crop protection.

The Effect of Neonatal Caffeine Withdrawal on the Memory of Newborn Drosophila melanogaster

Avery Kremer

Although warned about the potential risks of drinking caffeine during pregnancy, 4% of women continue caffeine consumption throughout their whole pregnancies. In cases of high caffeine ingestion throughout pregnancy, infants may present with neonatal withdrawal at birth. As this is not a widely studied issue, the goal of this project was to determine the impact of neonatal caffeine withdrawal on memory in Drosophila melanogaster.

In order to obtain newborn Drosophila, virgin females were separated and pretreated with caffeine prior to reproducing with males. Once newborns emerged from their pupal cases, their memory was tested during short and long term abstinence using negative reinforcement. Data was collected on the memory retaining abilities of the Drosophila. This data was later compared to previous testing on the effect of caffeine withdrawal on the memory of adult Drosophila.

Through testing, it was concluded that during short term abstinence, Drosophila had a low memory recall whereas during long term abstinence, Drosophila experienced an improved memory recall showing a recovery of memory retaining abilities over time. When compared to adult long term abstinence, neonates had a worse memory recall showing a longer duration of recovery. Overall, it is important that all of the potential risks that caffeine intake has on a developing fetus are understood in order for women to make the best decisions for themselves.

Long-Term Memory of Planaria Following Regeneration: Implications for Improving Future Dementia Treatment

Emily King

The innovation of treatment for memory loss and motor function can only be accomplished through an understanding of how regenerated brains and cells process memory retention. During a psychology class, the idea for this project was sparked when discussing the effects of memory loss on those with dementia and their caregivers. When a person's loved one has a memory-affected illness such as dementia, they start to lose themselves. What's even worse is those around them have to watch the illness progress. This can be heartbreaking and stressful for everyone involved. Memory loss becomes more severe over time which limits the options for treatment. Imagine if it was never too late and a different treatment could potentially give a person their memories and motor function back? The goal of measuring a planarian's memory recollection after cellular regeneration is to reveal the future possibilities on a human scale.

The project was conducted in three parts. First, the worms learned to go through a maze in order to reach food. A Y-maze was designed using Tinkercad and 3D printed. Ten groups of planaria were put through the maze six times before they learned the path to food. Next, planaria were cut laterally and half the flatworms regrew a tail, while the other half regrew a head. For two weeks, the planaria were monitored closely for movement and changes in features. Lastly, the flatworms were returned to the maze and timed to measure their speed and ability to reach their food. Following regeneration, 65% of the flatworms showed indications of long-term memory by reaching the food quickly.

In the future, this experiment will be replicated by designing a more challenging maze to see how detailed the planaria recollection can be. The evidence of memories in regenerated flatworms have the potential to change memory loss treatment, an understanding of the brain, and contributing to a more medically advanced society.

Impact of Type and Morphology of MPs on the Regeneration Rates of Planaria

Maeve Condron

Microplastics (MPs) are small particles, less than 5mm, that form when plastics break down. These plastics have been observed throughout out our environment and even within humans. To discover some of the effects MPs are having on humans, planaria were exposed to MPs of different sizes, compositions, and with different methods. Planaria were used because of their stem cells, called neoblasts, which mimic the stem cells humans use to create fetuses. There were 4 experimental and 2 control groups in this experiment. One group was fed MPs that were 0.01 cm across and composed of polyester. Another group was fed MPs that were 0.05 cm across and had mixed composition. The other two groups were each immersed in water in which one of the two kinds of MPs had been steeped. All groups were bisected and measured every 2-3 days for two weeks.

A Student T-Test was used to determine if the results were statistically significant. Only one experimental group passed the 10% benchmark, the group that was immersed in water that had had the larger, mixed composition MPs steeped in it. The results showed that the growth of this group was between 191% and 251% higher than the control groups. This result is contrary to what was proposed by the hypothesis and it is possible that the observed results were an example of hormesis. This would imply that MPs are causing damage to stem cells in the field, where exposure rates are much higher than what was used in this experiment.

The Influence of Ginger Root Extract on Female Reproductivity in Caenorhabditis elegans

Avery Leonard

In recent decades, infertility rates have risen globally, with 11% of women and 9% of men experiencing decreased fertility. Studies pertaining to male fertility are abundant, yet studies of female fertility are lacking in number and underfunded. As a result of the high costs and limited access to treatments for female fertility issues, there's a growing interest in more accessible solutions. Ginger, known for its medicinal properties, has been investigated as a way of enhancing male fertility; in this study, ginger's effect on female fertility was explored using the model organism C .elegans. Despite C.elegans primarily being hermaphrodites, they can express female fertility traits and are ideal for such studies due to their simple maintenance, short life cycles, and short reproductive cycles. Previous experiments indicate that ginger can be safely ingested by C.elegans and might even contribute to extending their lifespan.

This research aims to examine if a diet supplemented with ginger extract positively affects female fertility in C .elegans, focusing on egg production and progeny viability. It was hypothesized that ginger supplementation will increase both egg numbers and viable offspring compared to a control group. Quantitative analysis of data supports the potential of ginger extract as a natural female fertility enhancer, showing increased egg production and progeny viability in treated C. elegans

Remediating Oil-Contaminated Soil in Rural Colombia by Using Bacillus Subtilis for Sustainable Crop Growth

Eftalia Economou

Ndioba Fall

Located in rural Colombia, Puerto Boyacá is a small town with an economy primarily based on agriculture. This town's farms contribute to Colombia's major agricultural export of potatoes (Goldfajn, 2023). In addition, wheatgrass is widely used in the region to feed cattle. Despite the heavy reliance on agriculture, Colombia's primary export is petroleum, accounting for 50% of the nation's total exports – a 17% increase since 2006 (LaRose, 2022). Since its establishment in 2006, Mansarovar Energy, a leading Colombian oil and gas corporation, has contributed to 37 of the 109 oil spills that have contaminated the town's fertile farmland. These spills have affected the region's vital wetlands due to inadequate maintenance and overburdened oil pipelines, resulting in leaks and the release of oil. This pollution has led to a 90% loss in fish and the contamination of farmland since 2008 (Devia, 2023).

The consequences of this oil pollution extend beyond crops, impacting the people of Puerto Boyacá and Colombia at large. In 2021, approximately 16% of Colombia's 51.2 million population was employed in agriculture (Williams, 2023). Additionally, the local animal wildlife is being affected. During scorching summer days, with temperatures as high as 104°F, animals need to stay hydrated. However, the scarcity of uncontaminated freshwater sources often results in their death (Devia, 2023). This situation also directly affects the accessibility of fresh water for the human-residents in the region. The larger problem expanding outside of Puerto Boyacá is that the town's waterways run directly into the Magdalena River, Colombia's largest river, which flows through the entire western portion of the country (Whitley, 2020). This directly affects the accessibility of freshwater for the residents of the region. Addressing these oil spills is essential to reverse the negative impact on Puerto Boyacá, and Colombia's agricultural and economic sectors.

On March 24, 1989, the oil tanker named Exxon Valdez ran aground on Bligh Reef in Prince William Sound, Alaska, spilling an estimated 11 million gallons of crude oil. As a result of this, 1,300 miles of Alaska's total shoreline was oil-contaminated (Atlas & Hazen, 2011). To clean up 25-30% of this oil spill, natural degradation processes facilitated by microorganisms like Bacillus subtilis were applied to the contaminated site for the first 2 weeks after the spill occurred (Schmidt, 2012). B. subtilis is known for oil degradation producing enzymes, such as lipases and esterases (Wang et al., 2019). These enzymes break down complex hydrocarbons that the bacteria can utilize as a carbon source. B. subtilis are extremophiles, which means they can survive and thrive in extreme environments. This includes environments with high levels of hydrocarbons, like oil-contaminated soil or water. While oil-eating bacteria are most commonly used to clean up oil spills in saltwater, there has been limited research on their application to freshwater environments. My partner and I want to experiment with the application of B. subtilis on freshwater oil spills in soil, replicating the conditions of Puerto Boyacá, Colombia. Can the application of B. subtilis to oil-contaminated soil restore the soil's arability to be able to grow healthy vegetation?

Extend The Language of Love

Aimen Iqbal

Ayesha Shafi

Melania Frye

Flowers are significant to all of our lives, not only do they help the environment but they are also capable of bringing happiness to all that receive them. However, there exists an issue of flowers dying very quickly. When looking at how to extend their life, there is information that helps decipher that coins, bleach, flower solution, as well as simple plain water could potentially help with these issues. Therefore, if we add these various preservation solutions to the water that a flower is growing in, then it will result in the flower's life being extended.

Fungi versus Fast Fashion (The Effect of Oyster Mushrooms on the Decomposition of Different Clothing Materials)

Alyssa Kruger

Fast fashion is a global issue, caused by businesses accommodating rapidly changing fashion trends which result in large quantities of excess clothing. This clothing ends up in landfills, posing a threat to both the environment and communities near them. This experiment looked to Pleurotus ostreatus (Blue Oyster Mushrooms) as a solution to this excess clothing. It was hypothesized that these mushrooms would be able to decompose all clothing types used in the experiment.

Decomposition rates were observed after twenty one days of testing. A total of four different clothing types were used; cotton, denim, polyester, and a synthetic fiber made primarily of rayon. Each clothing type had two groups, a control group with no mushrooms and two samples per trial and another that had mushroom spawn with five samples per trial. At the end of each twenty one day trial, the net loss of mass was measured for each sample. The mass of denim decreased the most, with a decomposition rate of 5.51% in twenty-one days, which is roughly 15 times the rate of its control group. The t-tests performed also showed that the other clothing types were significantly different from the control. They all also demonstrated low standard deviations. Future research could better quantify the decomposition rates of inorganic clothing materials like polyester and synthetic fibers, once the mushrooms are more established. The results found in the experiment could be very beneficial to providing either an at home or larger scale system of decomposing unwanted clothing.

The Effects of Dead Sea Mud Minerals and Herbal Additives on the Regeneration of Dugesia tigrina.

Sasha Litvak

Dead Sea mud is rumored to be beneficial for healing skin conditions such as eczema and the reasons behind the benefits this mud contains have not been thoroughly investigated. Thus, it was decided that magnesium chloride and potassium chloride, key components known for their prominent roles in the cell cycle, were to be tested for boosting cell regrowth. Sea buckthorn oil and cayenne pepper were also included due to their anti-inflammatory and antiviral properties.

The investigation used Dugesia tigrina flatworms, notable for their efficient bodily regeneration. Nine petri dishes were set up for the experiment with three total trials, each containing twelve flatworms. Solutions consisted of either potassium chloride or magnesium chloride dissolved in water or of sea buckthorn oil or cayenne pepper in 15 grams of egg yolk. Each flatworm was beheaded and placed into a petri dish with their respective solution/mixture. It was found that it took the control group about eight days to regrow their eyes, but the group given 2g of sea buckthorn oil took only five days to do the same. The 1g of $MgCl_2$ and KCl groups took about 7 days, and 2g of said substances took about 6 days to regenerate. The cayenne pepper produced statistically insignificant results. All other trials were statistically significant.

According to the data collected, Dead Sea mud products that contain higher concentrations of $MgCl_2$, KCl, and sea buckthorn oil have a substantially higher effect on cell regeneration and could help treat skin conditions quicker than other substances.

Does The Color Matter?

Stella Czyzewski

Is there a difference between white and brown eggs in stores on the shelves and the various types (caged, free range, pasture raised, organic etc.)? I wanted to see if companies are in the right to market eggs (specifically brown) at such a high price and if it is really worth it to buy. Companys market eggs and label them to make eggs more appealing but is it necessary to buy them for x3 the price of white eggs. For my experiments I wanted to weigh the different eggs, their yolks, whites, shell and the egg as a whole. For the next experiment, I wanted to measure the thickness of the shell. For my last experiment, I wanted to compare the nutrition facts to see the differences nutrition wise. I found that the large brown Grade A free range eggs weighed the most in all categories as an average. I found that the Stop and Shop large white Grade A cage free eggs had the thickest shell and that the Vital Farms large brown Grade A pasture raised eggs had the most vitamins, minerals, and vibrant color out of all the eggs. In conclusion, the data shows that whether brown or white eggs are similar, the only difference is how the chicken is raised, its surrounding, and most importantly what it is fed, that play a key role. It will determine the color of the egg, thickness, and nutrional value. My personal opinion is, for white eggs is the Eggland's Best and for the brown the Vital Farms Eggs.

Filtration Capabilities of Different Chemicals for PFOAs and PFAS Molecules

Avaneesh Mohan

PFAS molecules have gone unnoticed for decades, and have been the root cause for many deadly forms of cancer, placental dysfunction, and various heart problems. PFAS have crept into many of the plastics and pans we use, but specifically our water supply. The PFAS molecules have been detected at microscope amounts, meaning conventional filters are not effective. The only real “solution” is reverse osmosis filters, which are unfortunately very wasteful, and use 5 gallons of water for every filtered 1 gallon, which isn’t good as this wastes lots of water. RO also loses many good nutrients. Instead, looking at the interaction between hSA and PFOA molecule specifically, we can characterize the reaction through hydrogen bonding, Van der Waals interactions, and hydrophobic interactions. To test this, my procedure was to have about 2 ml of water, and about 1% of the water should PFOA. We would the layer of chemical regent, and would then see how much of the PFOA has traveled to the subsequent layer. After letting it sit for 30 minutes each chemical regent, the highest filtration percentage was 94%. In the future, such regents can be used like chlorine treatments, and can filter out PFAS with efficacy and safety.

Synthesizing and Optimizing Biodegradable Pectin-Manuka Honey Hydrogels for Transcutaneous Electrical Nerve Stimulation (TENS) Therapy and its Applications in Tissue Engineering

Marko Mano

The field of hydrogels in regenerative medicine is experiencing a rapid revolution in cancer cell therapy , but an issue has arisen in regard to the environmental sustainability of the hydrogels. The original hypothesis stated that if a pectin-honey hydrogel consists of 2.0 grams of powdered fruit pectin, then the pectin-honey hydrogel would have the least resistance (in Ω) when compared to the pectin-honey hydrogels with 0.0 grams (control), 1.0 gram, 2.0 grams, 3.0 grams, and 3.5-grams of powdered fruit pectin.The engineering goal of the research project was to synthesize and optimize the amount of powdered fruit pectin to be an extremely efficient and effective semi-permeable membrane that promotes cell proliferation and conductivity in the intracellular membrane of mammal tissue which reduces the healing time of wounds. The research project consisted of the synthesis of 45 homogenous samples of biodegradable hydrogels that consisted of deionized water, Manuka-honey, and powdered fruit pectin as the cross-linking monomer. There were three different hydrogel samples (7.62 cm x 7.62 cm x 2.2 mm) made for five different measurements of powdered fruit pectin (0.0 grams, 1.0 grams, 2.0 grams, 3.0 grams, and 3.5 grams), which resulted in about fifteen hydrogel samples for each data set (three sets of data in total). Using a multimeter, an electrical current traveled from the positive probe to the negative probe, and the multimeter recorded the drop in voltage as resistance (in Ohms). The quantitative data concludes that the hydrogels consisting of 3.5 grams of powdered fruit pectin (cross-linking monomer) had the least electrical resistance (3.5-grams of pectin is 510.7 Ω) when compared to the other hydrogel samples made with 0.0 grams, 1.0 grams, 2.0 grams, and 3.0 grams of powdered fruit pectin. The average resistance for the hydrogel samples with 3.5 grams of pectin is 510.7 Ω, 0.0-grams of pectin (1785. (6) Ω), 1.0 grams of pectin (1349. (2) Ω), 2.0-grams of pectin (828 Ω), and 3.0-grams of pectin (694. (8) Ω). There is a clear inverse correlation because it was observed that as the amount of powdered fruit pectin increases, the electrical resistance (in Ohms) of the hydrogel decreases.

The conductivity of pectin solutions can be attributed to the ionized (carboxyl) groups of the pectin molecules in the solution. The pectin-honey hydrogel sample with the least resistance (samples with 3.5 grams of pectin) would prove to be the best for biomedical and tissue engineering uses, due to the fact that the more Ohms an object has, the more difficult it is for electricity to travel through it (Hatefi et al., 2023). Overall, it can be concluded that if a pectin-honey hydrogel composed of 3.5 grams of powdered fruit pectin were to be placed in the intracellular matrix of a wound, it would prove more efficient for biomedical uses in transcutaneous electric nerve stimulation therapy, which is further supported by the data that stated that the average resistance for the hydrogel samples with 3.5-grams of pectin is (510.7 Ω), which is much lower than the other samples consisting of 0-grams of pectin (1785.(6) Ω), 1.0-grams of pectin (1349.(2) Ω), 2.0-grams of pectin (828 Ω), and 3.0-grams of pectin (694.(8) Ω across the three sets of data. The conclusion drawn from the research can be used to help synthesize and mass-produce conductive pectin-manuka honey hydrogels for biomedical uses, specifically the treatment plans for patients suffering from chronic wounds (such as ulcers, burns, and surgical injuries), as by optimizing a pectin-manuka honey hydrogel, and have thereby synthesized a viable, biodegradable hydrogel that may help decrease the recovery time for individuals who are suffering from chronic wounds and as tissue scaffolding for regenerating tissue .

Producing a Biofuel From Peanut Shells

Jaiden Elber

Matthew Kellogg

The purpose of this experiment was to create a proof-of-concept for a method by which ethanol biofuel could be created from the cellulose found within cell walls in biomass. Cellulose is a long-chain fiber made from glucose molecules bonded together, via dehydration synthesis. By breaking down this polymer into glucose using the enzyme cellulase and water, the cell wall of a plant cell can be turned into a simple sugar which can be fermented using yeast into ethanol. This procedure had three steps: refinement of cellulose and the breakdown of that cellulose into glucose by hydrolysis, the fermentation of glucose into ethanol, and the distillation of ethanol. The refinement of cellulose was done by breaking down the cell wall using sodium hydroxide and then removing impurities by using the solvent xylenes. The cellulose was then broken down, and fermented, and the resulting slurry was then distilled using a relatively standard distillation setup. At the end of this experiment, no alcohol was found, but sugar was created from cellulose. The raw distillate contained a high amount of simple sugars, but no significant starches, which would include cellulose; these tests strongly suggest that every part of this experiment except for the fermentation took place, and even that, if the experiment was repeated with different yeast, the experiment would be a success. It was concluded that the process that took place does work but the yeast used was dead on arrival, causing it to not function the way it was supposed to.

Biochar's Potential for Mitigating Climate Change

Kyle Denny

Climate change is an issue that has been affecting the planet over the years. It may have been getting worse due to actions such as cutting down forests, the farming of more animals, and burning fossil fuels. Carbon dioxide is one of the main gases that has impacted climate change. Compared to other gases, carbon dioxide produces some of the temperature increases that the earth has been experiencing. As the demand for fossil fuels increases, the amount of carbon dioxide released into the atmosphere increases, which will make the Earth get even warmer. A warmer Earth means fewer places to live, heat-driven diseases intensifying, and greater weather changes.

This project aims to compare biochar and activated charcoal to filter carbon dioxide emissions out of the air. Biochar and activated charcoal are highly porous materials that can adsorb gases. According to Chen Zang in “The Application of Biochar for CO2 Capture: Influence of Biochar Preparation and CO2 Capture Reactor” biochar is an effective substance for adsorbing CO2. However, this project differs in that it also tests how much the biochar can retain after resting for a while to determine if it can be used for long term CO2 adsorption.

This is an interdisciplinary project that combines elements of engineering and chemistry.

A reusable filter chamber made from PVC was designed to test biochar and activated charcoal in both normal and CO2-enhanced air which created 4 test conditions. Each condition was tested five times with the two filter types resulting in a total of 20 trials.

A vacuum pump pulled air through tubing with PVC tube with a filter inside of the PVC. After 20 minutes of the vacuum pump running the filter was weighed then left for an hour to see how much the weight would change.

The results of the experiment showed that biochar can more efficiently retain carbon dioxide compared to activated charcoal. On average, there was an immediate weight gain of 0.078 grams for the biochar sachet after active filtration, but it lost 0.086 grams during inactive retention in CO2 enhanced gas. Meanwhile, the activated charcoal sachet on average gained 1. 112 grams during active filtration and lost 1.674 grams during inactive retention in CO2 enhanced gas. They behave very differently and an important factor affecting their performance is the amount of weight they retain after the resting period. These changes in mass show us that neither of these substances should be used for adsorbing CO2 due to having less weight now than they did at the start of testing. This is because it is not just important to measure how much each substance can adsorb short term but also how much of the gas it can retain over long periods of time.

Keywords: carbon dioxide; climate change; adsorb; biochar; activated charcoal; gas emissions

Selection of Green and Sustainable Bio-Based Solvent by Artificial Intelligence for Pharmaceutical Research and Process Development

Jack Li

Jayson Wang

The pharmaceutical industry is a major contributor to waste, primarily from the disposal of hazardous solvents, which pose risks to both human health and the environment. The adoption of eco-friendly alternatives, such as green and bio-based sustainable solvents, can mitigate these risks and protect the environment. However, the current process of identifying optimal solvent replacements involves time-consuming tests and additional costs. Our research project tackles this challenge by developing an innovative AI-driven model. This model predicts optimal substitutions for hazardous solvents, facilitating the transition from conventional, harmful solvents to green alternatives in pharmaceutical research and manufacturing processes.

To achieve this goal, we compiled a collective database of over 120 solvents, including their individual physicochemical properties. Utilizing the machine learning algorithms OPTICS/DBSCAN, we conducted a comprehensive six-dimensional analysis of all solvents. This led to the identification of Kamlet–Taft solvatochromic parameters and Hanson solubility parameters as the most relevant quantitative measures for comparing solvent similarities, correlating with solubility, reaction rate and equilibrium. After further iterations and analysis, we created a software algorithm capable of generating the top 10 most similar green and bio-based solvents for traditionally used hazardous solvents. Validation of our selection results was achieved by matching with examples from scientific literature. To make this information widely accessible, we developed a user-friendly cloud-based interface, which will be provided to the public free of charge.

Keywords: solvent substitution; solvent selection; artificial intelligence (AI); algorithm; green solvent; bio-based solvent; hazardous solvent

Investigating the Effect of Varying Pigment to Binder Ratios on Paint Performance

Nicholas Ramos

This study investigated the impact of varying pigment-to-binder ratios on the performance of acrylic paint, drawing on existing knowledge of the chemical properties of pigments and binders in paint formulations. The objective was to understand how these changes influence key paint properties, including drying time, color, adhesion, and opacity. The hypotheses tested stated that changing the pigment-to-binder ratio would result in statistically significant differences in these properties. Acrylic paints were formulated with three different pigments- Ultramarine Blue Light (PB29), Quinacridone Magenta (PV19), and Indian Yellow Tartrazine (PY100)- each at three ratios (1:6, 1:8, and 1:10), using acrylic gel medium as the binder. The data was evaluated using a combination of qualitative observations and statistical analyses, like ANOVA. Results showed significant differences in drying times across different ratios, as increasing pigment-to-binder ratios were associated with longer drying times. Significant differences in color properties were observed for PY100; However, the differences in color were not statistically significant across all pigments and ratios. Variations in adhesion suggested that higher ratios were generally associated with stronger adhesion, but were not statistically significant. Opacity, assessed qualitatively, suggested some minor differences between ratios, but the subjective nature of this assessment limited definitive conclusions. These findings contribute to an understanding of how pigment-to-binder ratios can affect paint properties, which is important for optimizing paint formulations for various applications. Future research could extend its scope to investigate the impact of additive interactions, varied binders, pigment characteristics, and beyond.

Determining the Sustainability of Different Wood Pellet Types

Max Donovan

Wood pellets, wood scraps that are compressed into a compact fuel, have been an increasingly important carbon-neutral energy source. The use of pellets for home heating and energy generation has grown in the U.S. and Europe. The purpose of this experiment was to determine the most sustainable type of wood pellet. Ten grams of pine, mixed softwood, mixed hardwood, pecan, and alder pellets were ignited individually, and data were collected regarding their respective energy outputs, smoke and ash particulate masses, and tree growth rates. Five replicates were conducted for each pellet type. After the initial data were collected, each pellet was graded based on its sustainability. It was found that the mixed softwood pellets were the most sustainable, and the pecan pellets were the least sustainable. Generally, pellets comprised of softwood fibers were more sustainable than those of hardwood fibers. It was hypothesized that the pine pellets would be the most sustainable, followed by the mixed softwood, followed by the pecan, followed by the mixed hardwood, followed lastly by the alder pellets. The hypothesis was somewhat supported, with the pellets made with softwoods performing better than the pellets made with hardwoods, however, none of the pellets performed exactly as expected. Wood pellets are manufactured using lumber industry waste. This information could be used by a pellet manufacturer to influence from which sawmills wood fibers are sourced, so as to create a more climate-friendly product.

Nanoparticle Guided Synthesis of Size-Tunable Photonic Crystals

Hayim Sims

Ever-growing reliance on communications technology has exposed a critical flaw in current electric circuits: stagnant speeds of transmission and heat loss debilitate an industry paramount for supporting our collaborative growth as a species. Photonic crystals have the potential to surpass traditional components by channeling light in a way that conventional matter cannot, enhancing the speed of transmission and reducing energy loss due to heat. The creation of photonic circuits necessitates the development of building blocks on the nanoscale, able to self-assemble into intricate and functional structures. Colloidal particles provide a pathway to photonic applications, but their synthesis remains a challenge within the 100-300 nm range which is essential for their interaction with visible light. This study explores the combination of materials at micro and nano scales to address this synthesis gap and create a system for photonic applications. Utilizing a seeded growth method of 3-(Trimethoxysilyl)propyl methacrylate (TPM) onto gold nanoparticles (AuNP), the size and dispersity of the composite particles was finely controlled by tuning TPM and AuNP concentrations. Specifically, by tuning the reaction for rapid growth on seeds, TPM particles each containing a single gold nanoparticle and demonstrating a narrow size distribution were obtained, as evidenced by precise measurements using scanning electron microscopy (SEM). Sedimentation of monodisperse particle suspensions via centrifugation led to size dependent structural coloration, and a series of blue, green, yellow, and red photonic crystals were obtained from increasingly large particles.

Analyses of particle volume and resulting crystalline coloration were implemented to derive whether addition of different growth procedures correlated to the resulting particle size and effects. Notably, structural coloration is shown to be angle-independent (isotropic), which is potentially caused by the glassy/disordered state of gold nanoparticles within the ordered TPM lattice. Isotropic photonic crystals are otherwise difficult to obtain, and this synthetic route may provide a rapid and scalable route to the bottom up synthesis of materials relevant for photonics applications.

The Food Additive for Long-Lasting Ice Cream

Riya Kanury

The purpose of this experiment is to test guar gum powder, strawberry powder, and gelatin in order to determine which food additive is the most effective in preserving ice cream from melting. I hypothesized that if guar gum powder, strawberry powder, and gelatin were added to three different bowls of ice cream, then the guar gum powder would preserve the ice cream the longest without melting, because it increases the viscosity of the ice cream, as well as the resistance to melting. For the experiment, I created three batches of homemade ice cream, using one of the three ice cream stabilizers in each one as well as creating an extra batch of ice cream with no stabilizer for a control. I did two trials of this and averaged the number of minutes recorded for more accurate data. Once this was done, I recorded the time for each type of ice cream to melt and the ice cream that took the longest to melt was my solution. I expected the guar gum power to have the most impact on the melting time of the ice cream. I accept my hypothesis because the ice cream with guar gum powder took an average of 46.51 minutes to melt, which is longer than the two other batches of ice cream with strawberry powder at average of 28.86 minutes and gelatin at an average of 31.84 minutes. These results show that the guar gum powder was more efficient in preserving the ice cream shape, and slowed down the melting rate by increasing the mixture's thickness.

Is There Plastic In Your Drinking Water?

Ansley Palermo

The goal of this experiment is to see if and or how different containers leach microplastics into water either with or without the aid of temperature change. If hot water is placed in a plastic container, there will be more microplastics present than in cold water because the heat will extract more of the plastic from the container, causing more plastics to make it into the water. This will occur the most in Polystyrene plastic because of its low quality and lack of firmness. This project contains three different tests. The first test is focused on how much plastic would leach if all the cups were in a room temperature environment. Four ounces of ultra pure water were poured into one Polystyrene cup, one Polypropylene cup, and one Glass cup. Each cup was covered with Saran Wrap and covered with a rubber band. From there, the three cups were placed on a countertop to sit. This process was repeated after 5 days. The second test is focused on how much plastic would leach if all the cups were in a really cold environment. Four ounces of ultra pure water were poured into one Polystyrene cup, one Polypropylene cup, and one Glass cup. Each cup was covered with Saran Wrap and secured with a rubber band. All three cups were placed in the freezer and the process repeated after five days. The third test was focused on how much plastic would leach if all the cups were placed under different heat increments. Four ounces of ultra pure water were poured into two Polystyrene cups, three Polypropylene cups, and two Glass cups. One Polystyrene cup went in the microwave for 30 seconds and the other for 1 minute 15 seconds. One Polypropylene cup went in the microwave for 30 seconds, another in for 1 minute 45 seconds, and the last one in for 2 minutes 45 seconds. One Glass cup went in the microwave for 30 seconds and the other for 2 minutes 45 seconds. After all of these tests were completed, each sample was taken to the lab to be observed under the microscope. The expected outcomes were that the Polystyrene cups would leach the most plastic and for the heat to make the most significant changes. Some of the significant outcomes of this experiment was that under room temperature conditions the Polystyrene produced the most microplastics, under really cold conditions Polystyrene produced the most microplastics, and under different increments of heat Polypropylene produced the most microplastics. Overall, the cups in the freezer produced the most amount of microplastics. In total, 51% of all particles found came from Polystyrene cups.

Revolutionizing Pain Relief: Sustainable and Controlled Delivery of Aspirin Using Biodegradable Microbeads for Enhanced Efficacy

Kritisha Agrawal

Key phrases: sodium alginate, drug delivery, reduction in administration of drugs, reduction in side effects of drugs, precise control, cross linking, reduction in waste, increase in accessibility, more sodium alginate leads to smaller drug release percentage

This research explores the development of hydrogels as a versatile platform for controlled drug release applications . Hydrogels, known for their biocompatibility and tunable properties, have immense potential in drug delivery. Sodium alginate, a natural biopolymer, is selected as the primary matrix material, and calcium chloride acts as the cross-linking agent. The study aims to understand the influence of various formulation parameters on drug release kinetics, with the ultimate goal of designing a hydrogel system that provides precise control over drug delivery.

In the initial stages, a sodium alginate solution is meticulously prepared by dissolving the biopolymer in deionized water. To enhance therapeutic potential, a model drug is incorporated into the solution, ensuring even distribution. Subsequently, hydrogel beads are formed by carefully introducing the sodium alginate solution into a calcium chloride bath. The hydrogel formation process is characterized by its porosity and swelling properties to better understand its structural aspects. The study then extends to systematic drug release experiments, investigating the impact of the concentration on drug release. The outcomes of these experiments are thoroughly analyzed, comparing variations in hydrogel composition and elucidating their effects on drug release profiles.

The discussion delves into the interpretation of results, drawing comparisons with existing literature on hydrogel-based drug delivery systems. Challenges encountered during the study are addressed, providing insights into potential areas of improvement. The study concludes by summarizing key findings and their implications, discussing the potential applications of the developed hydrogel system, and suggesting avenues for future research and refinement. This comprehensive investigation contributes to the growing body of knowledge in the design and optimization of hydrogel-based drug delivery systems for enhanced therapeutic outcomes.

Most importantly, hydrogels will serve the community. They will reduce waste because individual will not need to buy as much of the product. Additionally, hydrogels increase access to medication. Underprivleged people will not need to spend more money to constantly refill medication, which reduces the amount of money they need to spend.

Unmixing Mixture Using Chromatography

Avani Jain

Chromatography is a technique used to separate mixtures that can be done in many ways regardless of the state of matter.This experiment was about discovering how chromatography can be used to separate mixtures, and how different pHs and marker types affect the separation. I believe that a Black Crayola Marker combined with the most basic susbtance will provide the largest separation rate. In order to test this, I will be using five different types of markers (Crayola, Thin Sharpie, Thick Sharpie, Pen, and Permanent) in three different ink colors (Black, Blue, and Red). As the solvent, I will be using four substances of different pHs: Vinegar (pH of 2-3), Water (pH of 7), Isopropyl alcohol (pH of 8), and Bleach (pH of 11-13). Chromatography is a technique used by many fields of science to separate mixtures. Mixtures are substances made by combining two or more substances together and have two types: Homogenous, which are mixtures that are uniform throughout, and heterogeneous, which are mixtures that are not uniform throughout. Chromatography relies on the properties of polarity, adhesion, and cohesion in order to work. Water is considered a polar molecule, therefore only those substances considered polar will be able to attract strongly to water. Those substances that are non-polar tend to repel water. Cohesion and adhesion are the properties of water molecules to stick to each other and other types of molecules (respectively) which allows for the solvent and other components to travel up the chromatography paper. The result of this experiment was that Black Crayola Markers do have the highest separation rate, however, the best results occur in the most acidic substances. The lower the pH, the better the separation. In this experiment, it was key to keep the constants constant, as changing them even slightly would alter the chromatogram, which would then affect the entire result. These constants include the amount of solvent, the length of each paper strip, the amount of ink placed on the line, the temperature and environmental conditions, and the time they are placed in the solvent for. Chromatography and this experiment can be applied to many real-life situations, such as botany, pollution, and the medical field. Chromatography can be used to gain a deeper understanding of the photosynthetic pigments in plants similar to the way this experiment was performed. It can also be used to decrease pollution by separating the pollutant from the water and from the air using chromatography on a large scale. Chromatography is also used by many doctors to diagnose diseases by examining biological molecules and then prescribing the drugs.

‘Green’ Sunscreen: How Eco-Friendly is Your Sunscreen?

Moira Cosgrove

Sunscreen’s pollution in marine ecosystems is a common cause for damage to marine life. This experiment tests the difference in pollution concentrations of physical and chemical sunscreens. Physical sunscreen remains on top of the skin to act as a shield, while chemical sunscreen absorbs into the skin and acts as a sponge. The hypothesis is if a variety of sunscreens and dry times are tested, then the physical sunscreens with the most dry time will be the most environmentally friendly because of their composition. The hypothesis was tested by creating an experimental control set with known concentrations, creating solutions with these concentrations, taking the UV Index of each solution, and using the Beer-Lambert law to calculate the absorbance. The points were plotted on a scatter plot with the concentration as the x-variable and absorbance as the y-variable to determine a trendline. Both sunscreens were tested by exposing the sunscreen to water after different amounts of dry time, taking the UV Index of this solution, and calculating the absorbance. Based on the experimental control’s trendline, the concentration for each trial was calculated. The hypothesis was correct, as the physical sunscreen after 15 minutes of dry time had the lowest concentration and was therefore the most eco-friendly. However, for the shorter dry times, the chemical sunscreen had a lower concentration. The decrease in concentration levels for both sunscreens with more dry time was notable, as it dropped by nearly half from 0 to 7 minutes and again from 7 to 15 minutes.

How Does Flour Effect Baking Cookies?

Abby Taylor

Catherine Reinhart

This experiment investigated the effect of the size of a chocolate chip cookie when using different types of flour . For this experiment, three different types of flour were used: organic unbleached bread flour, gluten free baking flour, and gluten free almond flour. For each type of flour, the same amount of ingredients was used and only the type of flour was changed. The experiment was controlled by baking the cookies using each type of flour on the same day. The ingredients were measured using a digital food scale and were recorded onto a data sheet. A ruler was used to measure the width of each type of cookie. Our results show a strong correlation between the type of flour used and the size of the cookie. On average, the organic unbleached bread flour cookie had a width of 3 ⅓ inches. The gluten free baking flour cookie had an average width of 2.61 inches and the gluten free almond flour cookie had an average width of 4 ⅔ inches.

Revolutionizing Menstrual Hygiene: A Green Approach with Reusable Tampons

Molly Crawford

The goal of this engineering project was to create a reusable tampon that had optimal absorbancy and did not contain harmful chemicals such as titanium dioxide. Regular tampons create unnecessary large amounts of trash in landfills which is contributing to climate change. The tampons that were created were only made with natural and organic materials. They were tested by doing an absorbency test, a wear test, and a durability test. The reusable tampons had comparable results to the store-bought tampons in the absorbancy and wear tests. They had the greatest results compared to the store-bought tampons during the durability test. Reusable tampons are a concept that could benefit tampon users and people in the medical community all over the world.

From Waste to Fuel

Elias Castillo

Milo Isaacs

With the increasing risk of greenhouse gasses affecting the environment, different technologies that address and aid the climate issues are increasingly important. We chose to research biodigesters, which collect methane and other gasses released from compost, and attempted to construct and evaluate a homemade biodigester. We constructed a biodigester utilizing an airtight bucket filled with compost and water, tubing, two mason jars with water and steel wool, respectively, for filtration, and an inflatable inner tube to observe the collection of gas. Our first experiment utilized rabbit fecal pellets as the compost source. This first test showed no noticeable changes, with the inner tube showing no inflation, and no other indicators of biogas being produced. These results prompted changes to be made for the second experiment. A heating mat under the bucket was used to increase temperatures for better decomposition, and utilized horse manure mixed with fruits and vegetables for the compost. The second test showed some dried spills of the compost slurry outside the bucket, and a movement of some compost through the system to the water meant for filtration. The movement of compost further in the system, and the leaking of compost slurry through the top presents the possibility that gas production displaced the water, causing these results. Although the results weren't the desired outcome, they display the complexity of such systems, and present what needs to be addressed and fixed for future tests.

Data Driven Optimization of Pt-Based Ternary Alloy Catalysts for Hydrogen Fuel Cells

Jessica Tao

The arduous process of designing the optimal Pt-based ternary alloy catalyst poses a great barrier to the mass commercialization of hydrogen fuel cells. Given the vast possibilities of metal, combinations, their intricate interactions, and the catalyst's evolving nature, the trial-and-error experimental search for the optimal catalyst is practically unfeasible. Historically, there has been a great struggle to properly quantify and measure an alloy's atomic structure , metal composition, and morphology under operating conditions. However, with the introduction of calculating an alloy's lattice constant, we can greatly simplify this quantification. By establishing the relationship between the indicator for the chemical composition of an alloy and the catalyst performance—represented by lattice constant and mass activity— we present a method that streamlines this screening process. We propose that optimizing the lattice constant can pinpoint the highest mass activity and theoretically optimize the ternary alloy catalyst. To achieve this, we utilize data analysis techniques like multi-regression and skewed Gaussian distribution paired with Gaussian Process machine learning techniques. Further, we can use the equations to calculate a catalyst's lattice constant , chemical composition, and mass activity. This extremely versatile approach creates a blueprint for future catalysis development and can readily be expanded to different alloys and catalyst systems.

Can We Combat Drought with Fruit Peels?

Divine Omere

Kamiela Issa

The purpose of this experiment is to determine if the seeming waste from fruits can be turned into a potential solution for droughts around the world. Can drought be combated through fruit peels?

Drought has been a persistent global issue and while solutions like installing dams are in place, most of them aren't cost effective. Our hypothesis is that fruit peels help to retain moisture in soil better than the current preferred solutions. If fruit peels increase the moisture level of soil, it can be used as an effective means to grow crops in drought affected places. This process includes both artificial and natural materials to make mixtures that'll help the soil retain moisture. Other iterations include different concentrations of fruit mixtures and drying methods. Our experiment changes, we conducted by using different types of SAPs and changing our project duration. SAP, an acronym for super absorbent polymer, is a water absorbing hydroponic that can absorb water relative to its weight and is often used in agriculture.

For this research project, we plan to add our variables to the soil and over time measure the change in moisture with a soil moisture meter. The data we collect will tell us whether or not fruit peels are more effective than traditional SAP's.

The experimental data proved our hypothesis correct that fruit peels can be used to help retain moisture in soil better than other solutions preferred. The independent variable is the SAP's(superabsorbent polymer) and orange peel variables, and the dependent variable is the soil moisture. The data results go in order of first place to last place, with acrylic SAP with a pH level of 6.3, the orange peel solution with a pH level of 6.06, and the orange peel powder and sodium SAP tie with a pH level of 5.9. We could potentially improve our experiment by having the soil containers in an environment that replicated a drought, we could've also performed more precise measurements.

Computational and AI-Assisted Design of Dual-Metal Single-Atom Catalyst for Oxygen Reduction Reaction

Evan Xie

The electrocatalytic oxygen reduction reaction (ORR) plays a crucial role in numerous energy and sustainability systems such as fuel cells, metal-air batteries, and water electrolysers. It holds significant potential for renewable energy generation, transportation, and storage, heralding a cleaner and more sustainable future. Recent trends have shown increased use of single-atom catalysts (SACs), particularly metal-N4 moieties grown on graphene-based 2D materials, for enhancing ORR efficiency. However, the rational design of SACs for high-performance ORR faces challenges due to unclear structureproperty relationships and the limits of conventional experimental trial-and-error approaches. In this study, we leveraged the power of the density functional theory (DFT) calculations, combined with cutting-edge machine learning (ML) techniques, to explore 144 SACs featuring dual interacting M1-N4 and M2-N4 moieties (M1, M2 = Mn, Fe, Co, Ni, Cu, Ru, Rh, Pd, Ag, Ir, Pt, Au), denoted as M1-M2, grown on graphene. Of all the catalysts we examined, Fe-Pd emerged as the top performer, achieving an impressive overpotential of 0.211 V with respect to RHE in alkaline conditions — outperforming most previously reported SACs. Even more striking, 13 of the evaluated SACs surpassed a renowned benchmark catalyst, Fe(OH)-N4, in catalytic efficiency, including more economically viable alternatives like Fe-Ag, Ag-Cu, and Ag-Ag. Venturing further, we developed three ML models that accurately predicted the overpotentials of various M1-M2 SACs, showing their strong ability to capture the relationship between single-atom metal site properties and overpotential. These models provide useful tools for the rational design of effective electrocatalysts. Our study sheds light on the path toward achieving efficient SAC-catalyzed ORR, contributing to a more sustainable and energy-efficient future.
Keywords: single-atom catalyst, oxygen reduction reaction, density functional theory, machine learning, catalysis

Comparing Fire Extinguishing Solutions

Lily Bouyea

Logan Szenda

The purpose of this project is to conclude how well different soaps effectively, quickly, and safely extinguish different types of fires (class a and b). This is conducted by accounting for time of extinguishment of fire (measured in seconds), amount of solution used (measured in cups), and the environmentally friendliness of the solutions (measured by least amount of surfactants). Class A fire will be represented by wood and paper while Class B fire will be represented by diesel.

The solutions tested include Dawn dish soap, Pure-Castile soap, Ecos soap, Clean O2 soap, Universal Green 3% soap, and pure water. Each solution was tested twice for the time of extinguishment and averaged out to create bar graphs. To test each soap, a SUDS-N-SPRAY foaming washing system hooked onto a hose diluted the soap with water, delivering enough pressure and soap suds to suffocate the fire. The amount of solution used was determined by using a measuring cup and subtracting the approximate 2 cups of diesel used in the Class B fire testing, while Class A solution amount was not tested due to inaccuracies of absorption which was affected by the different sizes and amounts of wood and paper. Research on the amount of surfactants of each solution determined the environmental safety of each solution.

As working with fire and diesel (a highly flammable liquid) is dangerous, a local firefighter assisted with the experimentation by pouring the diesel, lighting the fires, extinguishing the fires, and discarding the solutions as the researchers stood a safe distance and recorded the data. The fire was lit inside of an aluminum tray on a metal stand which stood on the researchers driveway, far from any flammable materials or substances. The firefighter wore fire protective gear, also known as turnout gear, as a precaution to not get burned. The solutions were discarded by being poured into a bucket of cat litter (a very absorbent substance) and brought to our local recycling plant.

After experimentation results showed that the solution quickest to extinguish both Class A and B fires was Dawn dish soap while the most environmentally friendly solution was the Pure Castile soap. The high amount of surfactants in the Dawn dish soap allowed for quick and effective extinguishing of the fires. According to the National Fire Protection Association, there are 358,000 house fires and 70,000 wildfires across the U.S. every year. This research could aid in fighting these fires quickly and effectively while not harming our environment.

Virtual Screening as an Approach to Identify Small-Molecule CD38 inhibitors as a Potential Therapeutic for Alzheimer's Disease

Maxwell Wang

Alzheimer's disease is a neurodegenerative disease that affects millions of Americans each year and is consistently one of the top 10 leading causes of death in the United States. Limited preventative precautions combined with little knowledge on the topic leaves therapeutics that tranquilize Alzheimer's symptoms as the best way to combat the disease until further breakthroughs are made in the field. Alzheimer's disease therapeutics are designed to target and modify key proteins within the brain to hinder the processes that cause the disease. This project will discuss the background of Alzheimer's disease prevention, current theories, and the newly discovered CD38 protein, whose inhibition could be the key to emerging victorious against Alzheimer's disease. This project will also outline the virtual screening process and the discovery of a promising compound that could be used in an Alzheimer's disease therapeutic in the future. To conduct this experiment, online databases and simulations that utilize geometric, energetic, and machine learning methods were used to locate general binding locations on the target protein CD38. Then, potential small-molecule inhibitors were identified through pharmacophore-based virtual screening, and appropriate binding sites on CD38 for the potential molecules were investigated through molecular docking. Finally, virtual drug analysis evaluated each molecule's potential success as a drug. Through the rigorous qualification process, the single qualifying molecule, identified as ZINC22130252, was found and can be further researched as a potential therapeutic to aid in the fight against Alzheimer's disease.

Eco-Friendly Paint

Thavy Vanthon

The experiment was conducted to determine and compare the durability, quality, convenience, and human and environmental health of milk and oil-based paint usage. This experiment was divided into three tests. In test 1, online research evaluated the paint ingredients' impacts on human and environmental health. It has been shown that oil-based paint can cause poisoning. The main toxic ingredients in oil paints are hydrocarbons. In most oil paints metals like lead, mercury, cobalt, and barium are found. These metals can lead to poisoning if inhaled or consumed in significant quantities. Poisoning symptoms affect different parts of the body. They can cause irritation and blurred vision. The heart of the person affected might beat fast, and breathing could be fast, slow, or painful. They can also cause skin symptoms such as blisters, burning, and itching while stomach and intestine issues like abdominal pain, diarrhea, and nausea. These symptoms highlight the effects oil paint poisoning can have on the body. Not only can oil-based paint affect human health but it could also impact the environment as well.

Research has shown that oil paints are flammable. Oil paints contain large amounts of volatile organic compounds (VOC)s that are released into the air which causes air pollution. On the other hand, milk paint is made from milk, using a protein called casein, which binds paint pigments well. It is made by drying soured skim milk curd and mixing it with hydrated lime. Milk paint is eco-friendly and easy to make because it does not contain harmful chemicals that could potentially harm people or the environment. Test 2 was adhesion tests that determined paint durability by using tape and recording any chipping or peeling. It was found that oil paint had a lot more chipping and peeling than milk paint. For test 3, drying time tests were noted for paint convenience. It took 1 hour for the milk paint to dry up on the small canvas. The oil paint on the canvas never really dries up and has a sticky texture and stains. This can conclude that milk paint is safer, more convenient, and more durable than oil paint.

The Effects of Storage Conditions on Conductivity and Oxidation of Ti3C2Tx MXene films

Alexander Teymurazyan

This research investigated the impact of environmental factors, specifically water and oxygen, on the conductivity and degradation of thin films of titanium carbide MXenes, a novel class of two-dimensional materials. MXenes exhibit remarkable properties, including high conductivity comparable to metals, making them promising for applications in flexible and wearable electronic devices. However, MXene films undergo degradation over time, converting to less conductive titanium dioxide. The objectives of this study were twofold: to develop a non-invasive method for monitoring MXene film conductivity and to assess how the presence of water and oxygen influences conductivity.

Time-domain THz spectroscopy (THz TDS) was employed to map the spatial conductivity of six MXene films prepared and stored under various conditions over a month and a half. Films deposited from colloidal solutions onto quartz substrates were subjected to different storage environments, including vacuum, dry air, and ambient conditions. The results reveal that prolonged exposure to water significantly degraded MXene conductivity, particularly affecting the edges of individual nanosheets. Conversely, films stored in dry air exhibited minimal degradation, suggesting the importance of moisture in the degradation process. Moreover, the study demonstrated the efficacy of THz TDS in monitoring conductivity changes over large areas of MXene films. This investigation sheds light on the crucial role of environmental factors in MXene conductivity and offers insights for the development of durable MXene-based electronic devices. Future research will focus on developing strategies to protect MXene films from degradation, such as surface ligand attachment.

Preventing Abortive Spinal Surgery using a Novel Machine Learning Classification of Posterior Thoracolumbar Instrumentation Systems

Yaniv Taussky

Introduction: Posterior thoracolumbar surgeries occur when the thoracic or lumbar vertebrae are unstable, fractured or diseased. Over 300,000 surgeries were performed last year in the United States alone. Posterior thoracolumbar revision surgery often presents in an acute or emergency setting, and accurate identification of previously implanted hardware is necessary to use the correct removal and reconstruction equipment. Currently, however, no tools exist to reliably identify previously implanted hardware. With an accurate and reliable classification algorithm, doctors would be able to know the corresponding tools to use before surgery, preventing cases where the surgery must be delayed or aborted because of inadequate
supplies.
Methods: I received a total of 280 de-identified x-ray images of the thoracolumbar spine with
hardware in place from BIDMC Neurosurgery Division and University of Utah Department of
Neurosurgery. A total of 5 of the most commonly used spine hardware systems were analyzed:
Medtronic (n=65), Globus (n=75), DepuyExpedium (n=49), K2M (n=51), Nuvasive (n=40).
I initiated the testing of the constructed Convolutional Neural Network (CNN) by providing raw input data, opting not to incorporate any data augmentation techniques. This approach allowed me to assess the model's initial performance without artificially modifying the training dataset, providing a baseline understanding of its capabilities. After the preliminary results were suboptimal, I decided to evaluate if the model's performance was potentially being hindered by the scarcity of dataset, I undertook an augmentation experiment employing four strategies: zooming, rotation, blurring (added noise), and inversion. Subsequently, I further attempted to
increase accuracy by randomly pairing augmentation techniques, harnessing their combined effects to enhance the model's adaptability and robustness. This comprehensive data augmentation resulted in the highest accuracy.
Results:The model initially had 178 images. The CNN, without any augmentation, resulted in a 41.30% accuracy. The individual testing of each algorithm resulted in the following accuracies: rotation: 59.72%, zooming: 55.21%, blurring: 53.84%, and finally inversion with a 44.93% accuracy. The following tests were combinations of the augmentation algorithms, and addition of model layers. The most prominent combination accuracies are as follows: zooming & noise: 76.28%, rotation & noise: 83.84%, and the final model, a combination of rotation, noise, inversion, and the addition of a dropout layer resulted in a 97.48% accuracy.
Conclusion. After exploring over 20 combinations, the most effective configuration emerged, featuring rotation, blurring, inversion, and an additional dropout layer, which not only elevated performance but also addressed overfitting concerns, and resulted in the model having an accuracy of 97.48% demonstrating the intricate interplay between augmentation strategies and model architecture in achieving optimal results. The accuracy of these results may prevent abortive spine surgeries in the future where the correct hardware removal set is discovered intraoperatively to be incorrect.

Using Machine Learning to Develop a Novel Method of Drug Discovery for Estrogen Receptor Alpha Targeted Breast Cancer Treatment, Leading to Potential Drug Alternatives

Aishwaryalakshmi Saravanan

Breast cancer is the most common type of cancer in women in the United States, with around 245,000 women diagnosed each year. Over 80% of breast cancers are estrogen-receptor positive, meaning that the cells grow in response to estrogen, which is a hormone necessary for sexual and reproductive health. Estrogen carries out its role by binding to receptors such as estrogen receptor alpha. The ESR1 gene, which codes for that receptor to be made, will be expressed more for different people, meaning that more estrogen is able to bind to the receptor, leading to increased proliferation of breast tissue, which could develop into breast cancer. The best method to treat ER-positive breast cancer is through targeted therapy, which involves drugs such as Tamoxifen to specifically slow down the connection of estrogen to its receptor. While there is a search to increase the drug options available, the current drug discovery process costs over $2.8 billion and takes over a decade. The goal of my project was to create a machine learning model to predict the potency of a molecule for binding to ERα and inhibiting its function. The input of the model would be the molecule's structure in terms of a canonical SMILES string, and the model would extract descriptors to provide insight into the molecule's properties and behavior. That information would be used to predict the pIC50, a logarithmic value derived from IC50, or half-maximal inhibitory concentration, referring to the amount of drug needed to inhibit a biological process by fifty percent. A pIC50 above 6.0 would indicate a potent drug. After obtaining a dataset from the ChEMBL Database and completing feature engineering tasks, I used LazyPredict to build forty-one models, and I selected the best-performing models to retrain and tune hyperparameters for.

After comparing the results of those models with the most optimal hyperparameters, Random Forest had the lowest RMSE and highest R-squared value, so the model was recreated with more advanced hyperparameters and cross-validation. To expand the project, I created a large language model known as ChemBERTa and tested various hyperparameters, but the Random Forest model performed with a higher accuracy. The final Random Forest model was deployed to the Streamlit platform, where users can enter the canonical SMILES of a molecule and receive its pIC50 value for ERα-targeted treatment. Finally, I looped through a dataset to search for potent drugs, and many existing drugs were correctly predicted to have a pIC50 over 6.0. Additionally, I discovered two molecules, Diflunisal and Sotorasib, which can be potential drugs for a novel ERα-targeted breast cancer treatment.

Developing an Environmental Sensor, Designing, and Building a Sounding Rocket to Contain It

Elliot Stead

Altimeters are used to measure how high rockets go. In hobby rocketry, these are useful for competitions and various in-flight functions such as parachute deployment; however, they do not usually measure anything beyond height. The Adafruit CLUE is a microcomputer that has an array of sensors on it such as a pressure sensor, hydrometer, and temperature sensor. Additionally, the CLUE is cheaper than every altimeter that can export data to a computer on ApogeeRockets .com (a major hobby rocketry company). This project looks at developing a program to run on the CLUE to measure various environmental factors as well as altitude during a rocket flight and then output them to a computer for graphing. Additionally, this project looks at developing a rocket to house the CLUE and the various considerations and steps taken to design a safe and reliable rocket to conduct science in the air. Lastly, the CLUE was tested to find accuracy of altitude, and the conclusion is that its sensors are quite accurate.

Using Machine Learning to Detect Alzheimer's Disease in MRI Scans

Sam Lizotte

Alzheimer's Disease (AD) is a neurological disorder that targets the brain, slowly destroying cells that affect a patient's memory, thoughts, and behavior. AD often develops in the later stages of life, and is considered a tragic disease due to the fact that there is no way to reverse it. Because of the nature of this disorder, neurologists are actively trying to find a way to stop this disease, even though we have not found a cure yet. And while science is in the process of creating one, it is necessary to at least catch the disease in its early stages to ensure that the progression of the disease can at least be slowed. It also protects patients from other types of complications, because these neurological disorders make patients more vulnerable to other types of disorders. The problem with diagnosing this disease early; however, is that many ways that doctors use can be very expensive, time-consuming, or physically invasive. Because of this, I wondered if there was a simpler way to give patients at least an idea of what is going on in their brains. To do this, I used Magnetic Resonance Imaging (MRI) scans, which are often used in the diagnosing of other neurological disorders, while also being easier on the patient compared to alternatives. And while neurologists have already attempted this, I wondered if I could take it a step further by using different types of machine learning (ML) models. I used 4 ML models in total to test this hypothesis: decision trees, logistic regression, neural networks, and convolutional neural networks (CNN). After training the models to detect even the smallest differences in the dataset of images it was given, there were many surprising results in the accuracy. The most significant result I found was that the logistic regression model, not typically used for image processing, outdid the CNN: a model meant for image data. As a collective, most models reported 70% or above as an accuracy, but another significant result was that the most complicated model had an accuracy of only 53%. Overall, the models ranged in complexity, but the most complex models processed the image data through hundreds of layers minimum. The simplistic models performed worse than the complex ones, as expected, besides the outlier of 53% accuracy. While using machine learning did result in high accuracy, I still believe that it is not a perfect tool for detecting differences in MRI scans. MRI scans themselves are not made to detect AD; however, this project poses the possibility of MRI scans being used as a diagnostic in the future. Machine learning also needs to be developed a little more in order for this project to be properly efficient. This project will grow with the technology around it, and it does show that machine learning can be used for good, and hopefully one day, diagnosing Alzheimer's will be efficient and affordable.

Key Words: Alzheimer's Disease (AD), Magnetic Resonance Imaging (MRI), Machine Learning (ML), Decision Tree, Logistic Regression, Neural Network, Convolutional Neural Network (CNN), accuracy, model, image processing

ViMGuard: Automating Fact-Checking in Short-form Video Content with Video Masked Autoencoders for Misinformation Guarding

Andrew Kan

Christopher Kan

The rise of social media and short-form video (SFV) has inadvertently facilitated a breeding ground for misinformation. With the emergence of large language models, significant research has gone into curbing this misinformation problem with automatic false claim detection for text. Unfortunately, the automatic detection of misinformation in SFV is a more complex problem that remains largely unstudied. While text samples are monomodal (only containing words), SFVs comprise three different modalities: words, visuals, and non-linguistic audio. In this work, we introduce Video Masked Autoencoders for Misinformation Guarding (ViMGuard), the first deep-learning architecture capable of fact-checking an SFV through analysis of all three of its constituent modalities. ViMGuard leverages a dual-component system. First, Video and Audio Masked Autoencoders analyze the visual and non-linguistic audio elements of a video to discern its intention—specifically whether it intends to make an informative claim. If it is deemed that it has informative intent, the video is passed through our second component: a Retrieval Augmented Generation system that validates the factual accuracy of spoken words. In evaluation, ViMGuard outperformed three prior state-of-the-art fact-checkers it was benchmarked against, achieving accuracies of 81.3% and 89.2% on two independent datasets. To promote further testing and iteration, VimGuard was deployed into a Chrome extension and all code was open-sourced on GitHub. In summary, this work presents a novel approach to automated video fact-checking that outperforms all other known techniques. This breakthrough sets a new standard for SFV fact-checking and marks a significant stride toward trustworthy news on social platforms.

Keywords: deep learning, large language models, masked autoencoders, misinformation, multi-modal data, retrieval augmented generation, self-supervised learning, short-form video

DebateGPT: Assessing the Accuracy of Generative AI Responses to American Parliamentary Debate Queries Using a Custom Knowledge Database

Yuyuan Huang

Due to the impromptu nature of American parliamentary debate (APD), resources for APD debaters are relatively scarce. As such, there are few opportunities for debaters to practice and receive constructive feedback without private coaching, exacerbating inequality among debaters. Utilizing generative AI models like OpenAI's GPT-3.5 and GPT-4 may increase the accessibility of these types of resources. However, current models often lack the domain knowledge required to answer debate-related questions accurately. This study uses a custom domain knowledge base to investigate the accuracy of responses generated by the GPT-3.5 and GPT-4 models to APD-related queries of varying query specificity and knowledge dependency. I hypothesized that GPT-4, being the most recent model, would produce the most accurate results regardless of the question's knowledge dependency. Results reveal that providing the models with domain knowledge significantly enhances response accuracy for both models, although there is no significant difference between GPT-4 and GPT-3.5's performance. Furthermore, both models' performance significantly improved once the models were provided with knowledge from the database. Careful ethical considerations regarding the use of AI in education are recommended, emphasizing the pressing need for future research to explore the implications of employing generative AI tools in the classroom. This research not only holds significance for fields such as education, business, medicine, etc. in which domain knowledge is essential, but also contributes to the ongoing development of more accurate and contextually aware generative AI models and large language models.

Color Blindness

Arnav Gupta

My project was about color blindness, what causes it, and I made a solution for it. This is important because me and many others in the world are colorblind which can cause many problems in real life. There were no results but I was able to create a gadget. With this gadget you can hold it up to an object and it will tell you the color of the object. To conclude this research was important as we can further improve my solution or existing solutions.

The Accuracy of AI Generated Text Detectors at Detecting AI Generated vs Human Written Content

Myles Flores

There have been significant developments in artificial intelligence (AI) since the beginning of the year 2023. The advance of AI generators has allowed for rapid generation of sophisticated text responses. AI can be very useful but it is necessary to have the ability to accurately distinguish between AI generated text and human written text. This is important for maintaining ethical standards, protecting intellectual property, ensuring plagiarism free content, and preventing the spread of misinformation. This experiment aims to provide the accuracy of AI text detectors and allow us to understand which detectors are most accurate. If artificially intelligent generated text and human written text are analyzed by different AI text detectors then the most accurate detector can be known because one of the AI text detectors will have higher accuracy then the others. This experiment is testing four AI text detectors (Originality.ai, Turnitin, Winston AI, and ZeroGPT) which analyze responses. These detectors were chosen because they are most commonly used and regarded as being reputable. The responses that these detectors will be analyzing are both human written and AI generated from ChatGPT, CopyAI, and Google BARD (recently renamed Google Gemini). The AI text detector provides each analyzed response with a percentage which refers to the predicted amount of AI generated text in that response. After experimentation, Turnitin's accuracy was not found because not all responses were over 300 words which the detector required. OriginalityAI had the highest accuracy of 86%. Followed by ZeroGPT with an accuracy of 62% and then Winston AI with an accuracy of 60%. From further analysis of the data, it was found that the AI text detectors were always correct when analyzing AI generated text but when analyzing human written text were incorrect 67% of the time.

Can We Enhance Our Breathing Habits to Prevent Potential Future Health Issues?

David Letelier

This study integrates technology and computer science to monitor and visualize diverse breathing patterns in real -time, emphasizing thoracic and diaphragmatic breathing. Utilizing stretch sensor strips, the research explores tailored interventions to positively impact breathing, expanding the scope of health monitoring beyond traditional vital signs for enhanced well-being.

FeatherAI 2.0

Gabriel Neves

Jay Bhatia

Mukilan Dayasankar

FeatherAI 2.0 is an entirely rewritten successor to FeatherAI. FeatherAI 2.0 records, transcribes, and summarizes audio input in the form of human speech. It uses JavaScript and ChatGPT from OpenAI and features its own webpage. Multiple prototypes were made, and the final iteration of FeatherAI 2.0 results in advanced, detailed summarization of audio input. The prototyping process involved adding features on top of each functioning prototype until the final product was programmed, Each interaction added more features once the previous version was verified to be working correctly to ensure a properly functioning product.

ALLocate: A Low-Cost Automatic Artificial Intelligence System for the Real-Time Localization and Classification of Acute Myeloid Leukemia in Bone Marrow Smears

Ethan Yan

The precise and accurate leukemia detection in current clinical practice still remains challenging due to limitations in cost, time, and medical experience. To address this issue, this research aims to develop the first integrated low-cost automatic artificial intelligence system for the real-time localization and classification of acute myeloid leukemia in bone marrow smears, named ALLocate. This system consists of an automatic microscope stage, an image sampling system, and a deep learning-based localization and classification system. For the deep learning model development, 50 de-identified whole slide scanned images of bone marrow aspirate smears were selected. A region classifier using a convolutional neural network (CNN) model was developed to select usable regions from unusable blood and clot regions. To achieve cell segmentation, a U-net based model was established in usable marrow regions. For real-time detection, the YOLOv8 model was developed and optimized. The key variables for optimization include the number of epochs, learning rate, and network architecture. These models show high performance with a region classifier accuracy of 96%, U-net accuracy of 85%, and YOLOv8 mAP of 91%. In addition, a low-cost automatic microscope stage and scanner system was developed using 3D-printed pieces controlled by stepper motors and a RAMPS control board. When ALLocate was applied to a marrow smear, its leukemia detection results are similar to the results from a doctor, but it is much faster. This is the first report to integrate the deep learning system with low cost microscope automatic stage and scanner system for leukemia detection. For small community practices or clinics in underserved areas, the developed ALLocate can significantly improve the efficiency of leukemia detection from the marrow smears and make healthcare more accessible and affordable to all .

A Generative Multimodal Approach to Improve Detection of Lung Cancer

Pranay Kocheta

As the use of AI in medical imaging has increased, so has the need to explain a model's results. Segmentation models are one technique used to produce explainable results. Due to larger size and sophistication, segmentation models which operate on 2D data can often produce better re-sults than models operating on 3D data. In the real world, imaging is combined with clinical fac-tors for diagnosis. To replicate this, multimodal models are used which combine image and text modalities. Finally, a lack of high quality data can hinder a models ability to perform in the real world but a solution that has been on the rise is generative models. I propose a multimodal ar-rangement that converts 3D scans to 2D and uses a 2D segmentation model (DeepLabV3) to an-alyze the images. This is combined with a pretrained MLP on variational autoencoder (VAE) generated biomarkers to achieve a complete confidence score. Using the Medical Segmentation Decathlon Lung (MSDL) dataset and the LUng CAncer Screening dataset (LUCAS), I achieved a testing Dice coefficient of 0.91 on segmentation with a receiver operating characteristic (ROC), average precision (AP), and F-Score of 0.83, 0.86, and 0.85 on the final multimodal results.

AI-Based Fire Monitoring System

Lukeman Nouri

During a forest fire, every minute counts. Each moment that a fire goes unreported or unnoticed, further environmental damages are imposed that can leave the affected area stripped of biodiversity for years . Current detection methods such as satellite technology have a substantial delay and only detect fires once they reach a critically dangerous size. NASA estimates that current imaging and detection technology allows most forest fires to be detected in 4 hours. (NASA 2019). Unfortunately, this margin remains too large for most firefighters as reported by Vince Ambrosia , a wildfires remote-sensing scientist at NASA's Ames Research Center who states that "firefighters want to be able to get on a fire … within the first hour so they can take action to put it out" (NASA 2019). To minimize the delay in forest fire reportings , I configured a CNN (Convolutional Neural Network), a form of AI, to a Raspberry Pi to serve as a mobile continuous fire monitoring system. Through this software, the Raspberry Pi can indefinitely and autonomously monitor a given area of land and report any concerning visuals to local fire mitigating authorities.

Identifying Rapidly Evolving Genes in Coral Species to Better Understand Coral Bleaching

Adrita Samanta

Coral reefs are home to millions of animals, but reef populations are rapidly declining due to pollution and climate change [1]. Corals consist of multiple living organisms existing in symbiosis. The two main components of corals are the coral animal, which has polyps, and the Symbiont algae, which provides the corals with nutrients that are essential to their survival [2]. When corals are stressed, possibly due to rising ocean temperatures, they expel their algae and bleach. If the corals stay bleached for long periods of time, they starve and die. Recently, the genomes of multiple species of corals have been sequenced. We wanted to use computational methods to observe the differences between these coral species. Knowing how these species differ, can help us begin to understand how these differences could affect the coral species' responses to stress. We decided to look for rapidly evolving coral animal genes because they would be the most involved in adapting to different environments across species. To do this we first used BioMart [3] to identify orthologous genes in two coral species which were chosen based on the better availability of their genomic data, specifically, Acropora millepora and Stylophora pistillata. Then to find the genes that are rapidly evolving we compared the orthologous genes using a computational tool called dN/dS [4, 5] which measures the ratio of nonsynonymous (mutations to the nucleotide sequence that changes the amino acid) to synonymous mutations. However, to compute dN/dS reliably, we want to compare the genes based on how evolutionary close or distant they are. We created a species tree to represent the evolutionary distance using MASH [6], a method for measuring global mutation distances using smaller subsequences of the original genome. We then used MAFFT (Multiple Alignment using Fast Fourier Transform) [7] to create a multiple sequence alignment from orthologs across the different coral species guided by the species tree. We selected orthologs in our two chosen species whose dN/dS values were greater than 1. These selected orthologs are positively selected which means the gene might have evolved to its current state because it's advantageous to the organism. We then used functional genomics approaches like transferring Gene Ontology [8] labels from orthologous proteins in better-studied species to investigate these "interesting" genes in more detail. We hypothesize that our work can provide an overview of the evolution of coral genes that might have been affected by environmental stressors such as rising ocean temperatures as a consequence of global warming, pollution, and lack of sufficient nutrients.

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Machine Learning Classification Using Neural Networks and Transfer Learning on CT Scans of 4 Lung Cancer Subtypes

Juliette Clausen

Niyathi Srinivasan

Siya Setty

Early detection of lung cancer is vital to survival, as lung cancer is the leading cause of cancer-related deaths around the world. However, lung cancer has variable clinical presentations, so diagnosis, even by trained medical professionals, is challenging and time-consuming. Deep Learning (DL) has proven effective in training big data to generate accurate diagnoses through machine learning classification. We found a dataset composed of computed tomography (CT) images of patients with one of the following: 1) lung cancers in the categories of adenocarcinoma, large cell carcinoma, and squamous cell carcinoma, or 2) a normal chest scan. We developed a DL model using a convolutional neural network framework to classify images in this dataset using Google's collaborative software. We implemented a variety of architectures for feature extraction using transfer learning as well as hyperparameter optimization methods and data augmentation and enhancement tactics to observe the impact on a variety of different metrics such as validation accuracy, statistical errors, and learning rate. After adding dropout layers and tuning our hyperparameters with the keras.tuner library's functions on the EfficientNetB0 architecture, we achieved a test accuracy of 98.92%. Based on our heat map, our model correctly identified regions where malignancy is prevalent across all four classes. We also utilized Google's Gemini model in conjunction with our machine learning to explain incorrect classifications to the layperson.

SplattingTAPIR: Utilizing TAPIR and 3D Gaussian Splatting for Efficient & Robust Reconstruction

Tim Nguyen

We present SplattingTAPIR, a deep-learning twist on a classical visual odometry problem. SplattingTAPIR is a robust and efficient end-to-end pipeline that can transform a set of 2D images into a 3D scene using the Tracking Any Point with per-frame Initialization and temporal Refinement (TAPIR) network for 2D keypoint detection with the traditional monocular pose estimation algorithms and combining this work with 3D Gaussian Splatting. SplattingTAPIR unique architecture utilizes TAPIR to robustly perform “zero-shot” predictions on a set of keypoints across a track of frames, rivaling classical keypoint detector and descriptor algorithms in both speed and accuracy. TAPIR has proven to be much more robust against texture-less materials and noise than its classical peers. In addition to TAPIR, 3D Gaussian Splatting brings a whole new level of immersion in both quality and speed that is unparalleled compared to classical 3D reconstruction techniques and current state-of-the-art neural renderers. SplattingTAPIR outperforms classical approaches by over 1.28 when it comes to camera pose translational estimation accuracy and is up to 549 times faster when compared to other classical 3D reconstruction workflows.

Keywords: Photogrammetry, Photo reconstruction, Optimization, Computer Vision, 3D Objects, Depth Perception, SIFT, ORB, Machine Learning, JAX, TensorFlow, 3D Gaussian Splatting, NeRFs

AI-Powered User Carbon Efficiency

Mihir Shenoy

Electricity usage generates carbon emissions since it is generated from fossil fuel sources such as natural gas or coal. The carbon intensity of electricity keeps changing from one hour to the next due to changes in the generation source and demand at a certain time. If you can do more chores such as laundry or EV Charging when carbon intensity is lower, it can reduce the total carbon footprint of a household. If prediction of carbon intensity is possible then it can be used to perform chores at certain times of the day in order to reduce carbon emissions.

My hypothesis is that if past carbon intensity is known, it is possible to predict the future carbon intensity for a time period using AI techniques. Further, if a prediction of carbon intensity is given, it can be used to schedule common tasks during periods of lower carbon intensity which will reduce total daily emissions. Using carbon intensity data from the electric grid, I developed an AI based prediction model to predict the periods when carbon intensity is at its lowest . I tested the accuracy of the model on example test data to ensure good prediction performance. I also built a tool for recommending users to do their household chores during the predicted periods of lowest carbon intensity.

Comparison of Accuracy and Carbon Emission of U-Net Variations Across Various Optimizers and Loss Functions

Kaiwei Yang

In the rapidly evolving landscape of artificial intelligence (AI), the quest for accuracy has long dominated discussions on model performance. However, as concerns about environmental sustainability grow, a shift in perspective is emerging—one that intertwines accuracy with the carbon footprint of training processes. This paper showcases and analyzes the performance of different model, optimizer, and loss function combinations in terms of accuracy and their corresponding CO2 emissions when applied to an image segmentation problem. Numerous U-Net variations from the original U-Net to models bridging U-Nets and Transformers, such as Attention U-Net and TransUNet are trained and evaluated with fifteen loss functions and eight optimizers to identify roads from satellite images. The analysis reveals a pivotal juncture in AI research, highlighting the symbiotic relationship between technological excellence and ecological responsibility. We discover that specific model, optimizer, and loss function combinations may achieve significantly lower carbon emissions while maintaining similar accuracy levels. This discovery acts as a catalyst for innovation, motivating researchers to explore eco-friendly optimization techniques and industries to recalibrate benchmarks for success, instead of only emphasizing accuracy. The recalibration transcends AI, resonating across disciplines and industries, urging us to envision a future where technology advances coexist harmoniously with environmental stewardship.

Secure Code Generation with Large Language Models

Ruichen Zhu

In recent years, the proliferation of code generation models based on large language models like GitHub Copilot and ChatGPT allows automated source code generation to the requirements of the developer , and significantly increased coding efficiency. However, a recent study revealed security concerns in generated code, leading the code to be vulnerable to attacks. Our research introduces a framework aimed at mitigating the risk of code generation model generating vulnerable code specific to authorization issues. We developed a ranker that uses VUDENC , a deep learning model for vulnerability detection, along with CodeQL and Bandit , two Python code analyzers, to evaluate and rank generated code based on security metrics. By generating multiple code candidates and utilizing the ranker to select the most secure option, our approach ensures a generation of more secure code. We evaluate our framework on the SecurityEval dataset on relevant problems, which shows our code has newfound advantages when compared to the gpt3.5-turbo model. With its proven effectiveness, the framework could be expanding its applicability beyond authorization issue, adapting to mitigate a comprehensive range of vulnerabilities.

Animated Drawings Used for Emotion Detection and Expression

Shawn Wei

Some children may struggle to express their emotions to people around them, preventing others from getting to know them or helping them when needed. One way to help children better express themselves is through drawings. Many scholars in psychology have looked into this, including the HTP(house tree person) test and MAPD(multilevel analysis of projective drawing). These are ways of reaching the inner world of the children.

In this project, I incorporated MAPD(multilevel analysis of projective drawing), a simplified version of the HTP test, with an animated drawing model. Using about 1500 photos labeled happy or angry, I found that accuracy is still relatively low. This is likely due to the images being highly random, which I believe best shows how using drawings could be very effective at reaching children's minds. Everyone's drawings are completely different and show their style. Then, an animated drawing model is used to bring the characters to life. However, I find this model difficult to personalize, making it difficult for children to express themselves through it genuinely, however, after testing with next-frame generation models, which seem to be much more personalized for each drawing. This part is still only being developed, though.

I believe this research/ project could be used with many children who can't communicate their feelings through words, which could help close the gap between people around them.

Curated AI as a Solution to News Deserts

Joel Lederman

The primary goal of this project was to utilize transcription technology together with the recently developed ChatGPT text generating software to write local news articles. The decline in the financial viability of the local news industry has resulted in the elimination of large numbers of newspapers both throughout the United States and in Marblehead, the town used as the test case. Today, in the wake of the Covid pandemic, local and state governments often record meetings and upload them to various platforms. From there, these recordings can be converted to mp3 format, and then transcribed. Although many transcription services were considered, the Deepgram software was chosen due to its higher transcription quality and easy API integration. After initially using the ChatGPT web interface to test its ability to generate articles, the ChatGPT API was utilized to combine both transcription and article creation into one application. Throughout the project, many problems arose, including inaccurate subjective commentary, mislabeled speakers, omission of key topics, and inadequate length. To fix these errors, the code and commands to ChatGPT required constant development and customization. While the original goal was to include analysis, ChatGPT lacks the intuition and context to do so accurately. As a result, the project was adapted to only produce factual summaries of meetings. While this approach did produce viable articles, both the AI and the available transcription software still incorporate mistakes that must be corrected through human curation.

The Relationship Between Social Media and High Schooler Mental Health and the Efficacy of AI Models in Predicting Stress Levels among High School Students Using Social Media Posts

Daniel Guo

Addressing the critical concern of stress among adolescents, highlighted by health organizations' declaration of a national emergency in children's mental health, this study uses the widespread use of smartphones and social media to predict stress levels in high school students. Traditional psychological assessments like the Perceived Stress Scale (PSS-14) are difficult to consistently use, prompting this study's shift towards digital platforms such as Instagram and Snapchat, where engagement is high among teens. Utilizing Convolutional Neural Networks (CNNs) for prediction and the Statistical Package for the Social Sciences (SPSS) for statistical evaluation, this study develops a predictive model based on data collected through psychological surveys. By focusing on platforms that offer more insight into adolescent life compared to text-based social media, this study aims to uncover the relationship between social media use and stress levels. By integrating image processing with detailed statistical analysis, the research provides new perspectives on detecting and understanding adolescent stress in relation to social media, offering pathways for targeted mental health interventions.

An Application that Directs Users to Seeking Treatment from Urgent Care, Emergency Care, or at Home for Common Traumatic Injuries

Neha Nagireddy

In this project, the focus is on addressing the critical issue of uneducated healthcare facility choices for traumatic injuries, which account for 32.1% of Emergency Department Visits. The proposed solution is an iOS application called MediChoose, developed using Swift and SwiftUI, featuring a weighted scoring system to assess injury severity accurately in an overall severity score. The application aims to reduce unnecessary visits, costs, and healthcare facility overcrowding by providing tailored recommendations for Urgent Care, Emergency Care, or Home Monitoring based on injury severity. By the current time frame, this application currently asses the common traumatic injury of burns to showcase this application's potential. While alternative solutions like WebMD Symptom Checker, telemedicine, and AI medical tools exist, their limitations in addressing traumatic injuries with specificity and accuracy make them inaccurate. The accuracy of MediChoose was calculated to be 94% overall, having a 100% accuracy in directing users to Urgent Care, Emergency Care, or Home based on the algorithmic output, and having a 94% accurate algorithm. When analyzing scenarios MediChoose deemed to be appropriate for Home Care the coefficient of variation was calculated to be approximately 7.85%. When analyzing scenarios MediChoose's algorithm deemed to be appropriate for Urgent Care, the coefficient of variation was 13.5%. When analyzing scenarios MediChoose deemed to be appropriate for Emergency Care, the coefficient of variation percentage for MediChoose's algorithm was 9.27%. Overall MediChoose is clearly a promising and stable solution, yet the author would like to further improve its accuracy through collaboration with medical professionals.

How Can the Number of Victims Who Experience a Swatting Crime be Reduced through the Development and Implementation of Artificial Intelligence?

Tyler Scaringella

The escalation of swatting incidents has become a significant public safety concern in the United States . With swatting calls on the rise, affecting hundreds of individuals and institutions annually , the need for an effective solution to identify and mitigate these incidents has never been more critical. This project presents the development and evaluation of an artificial intelligence model designed to differentiate between authentic and hoax emergency calls through binary text classification . Utilizing features extracted from the calls and embedding them into a vector input for classification, the model demonstrated a promising accuracy rate of 98% in identifying the nature of the calls.

Automatic Waste Classification System

Daksh Dalal

Rationale: In today's world, one of the obstacles to waste recycling is improper classification and sorting of waste at the point of waste generation. This problem is in every household in the world today. We currently depend on human beings to make the right decision regarding where the domestic waste should be collected i.e. recycle, trash or compost. For example, in 2014 data collected by the EPA shows that 34.6% of the 258 million tons of trash created was actually recycled due to lack of participation and incorrect sorting. The rest either ended up in landfills or was combusted. The lack of recycling due to the incorrect sorting is the problems this project will solve. Domestic waste includes food waste, paper, glass, metals, plastics, textiles, etc. A large part of domestic waste also consists of plant and animal waste such as vegetables, fruit peel, bone and meat waste, and chicken and fish waste.

My project addresses this problem of "incorrect" waste classification at the point waste generation by automating the process of waste classification and sorting.

Early Detection of Drug Toxicity

Ishana Saroha

Toxicity prediction of drugs is a critical step in the drug development process , as it evaluates the safety of drugs. An abundance of resources go into the development of new drugs, yet only 12% of all drugs are considered by the FDA, since many potential drugs are toxic. By the time toxicity has been identified in conventionally developed drugs, anywhere from $1 to $2 billion could've been invested. Therefore, it is imperative to have an early detection of drug toxicity. AI can be used to predict toxicity, by using QSAR and machine learning methods. Some ML based (DNN, SVM, RF) solutions have been proposed that use only molecular features of the compounds, not molecular structure. The goal of this project was to create a GNN ML model (which uses both atomic features and molecular structure information) that could make better toxicity predictions. Tox21 toxicity dataset was used for all training and evaluation. Three GNN models were created and then compared to a SVM model. Statistical analysis of results showed that the GNN models performed better than the SVM model, with the GNN models having better F1-scores (3.34%-6.44% improvement) and MCC values (5.48%-9.40% improvement). Results of this project show that GNN-based models have better toxicity prediction compared to SVM-based models. GNNs have great potential to augment existing QSAR methods used in predicting toxicity in the drug development industry, thus reducing cost, time and resources invested, and alleviating ethical concerns of animals/clinical trials when compared to conventionally developed drugs. This model can help in molecule toxicity prediction for pharmaceutical and other industries.

Keywords: Drug toxicity, Artificial Intelligence (AI), Machine learning, QSAR, Graph Neural Networks(GNN), SVM, Tox21

Innovative Natural Language Processing for Extracting Social Determinants of Health from Clinical Notes

Aniketh Mahesh

Social determinants of health (SDOH) are socioeconomic factors that have a profound impact on individuals' well-being and determining them can lead to informed clinical decision-making. However, obtaining SDOH are not readily available as they are stored in electronic health records (EHR) as free-form text, rather than structured data. The extraction of such data requires data-driven information extraction models trained extensively upon large corpora, resulting in an ineffective output by itself, needing human intervention. Additionally, this form of extraction oversimplifies critical determinants, often giving an incompetent output. This study utilizes a combination of language learning models (LLM), Bidirectional Encoder Representations from Transformers (BERT) pretrained models, structured upon a novel multi-layer architecture to extract major determinants with precision and limited human intervention–visualized outputs. These models will be fined upon named entity recognition (NER), a method untested with layered architecture and MIMIC-influenced SHAC data. This approach will avoid the distortion of variables of a determinant and enable the extraction of data into a user-friendly format in a timely manner. The results from this project present an NLP with visualization and accuracy with an overall Macro F 1 of 79.69% across all determinants. Although slightly underperforming among the current extraction methods, due to data limitations, this method allows for an accurate extraction with detailed visualization. The effect of this study not only aids in further exploration of multilayer architecture for visualization but also enhances the use of SDOHs for better health outcomes.
Keywords: SDOH; deep learning; layered architecture; natural language processing; named entity recognition; visualization.

SecondSaver: A Mobile App to Alert Drivers and Prevent Car Crashes

Jasmine Palit

Fatalities and serious injuries from automobile accidents continue to be a public health issue. It is a major cause of deaths and injuries among teens, who are just learning to drive. Meanwhile, rates of accidents from distracted driving have increased, especially with the pervasive use of cellphones during driving despite strict laws against such actions. The issue can get exacerbated with teen drivers, who are typically just learning to drive and are accustomed to using mobile devices at all times, making them especially susceptible to distracted driving. While driver safety technologies have become prevalent in passenger vehicles and many are equipped with technology to help navigate obstructions or lanes, only a few newer model cars have the ability to alert drivers when they are approaching the vehicle in front of them at a dangerously fast speed. A distracted teen driver will be hard-pressed to keep a reasonable safe distance at all times from the vehicle in front. SecondSaver is a mobile app that uses AI and accelerometer/GPS data from a smartphone to help the driver maintain a minimum three-second distance behind the car in front of them at all speeds. The app was developed using Android Studio. It utilizes a smartphone's accelerometer and GPS to find the instantaneous velocity of the car. Additionally, the app uses a machine learning (ML) computer vision model that detects and finds the area of the license plate of the vehicle in front, which provides an estimate of its distance. The app uses an online ML model hosted by Roboflow that was trained using transfer learning with several hundred custom images of vehicles with license plates. This model is accessed by the app whose custom UI was coded using Python. The vehicle distance information is paired with the speed data from the accelerometer. The SecondSaver app can then calculate the "time-distance" between the driver and the vehicle in front of them. The app warns the user using audible alerts if the driver is getting too close to the vehicle in front, by comparing the computed "time-distance" at the current speed to a pre-defined threshold (say three second-distance). This application is designed to help decrease tailgating accidents due to distracted driving and keep roads safer and save lives. This is especially pertinent to teen drivers who are inexperienced, are prone to more risk-taking (e.g., tailgating) and being more attached to their cellphones, even while driving.

Improving Drug Discovery by Utilizing Machine Learning Algorithms and Biological Activity Data of Target Proteins

Lagnajeet Panigrahi

Humans have been battling the age-old battle against illness for centuries. Recently, humans have made significant progress in averting illness through the creation of drugs and the field of drug discovery. To create a drug and deem it usable requires a rigorous process that examines one attribute in particular: safety. Unfortunately, 90% of drug development fails despite the successful strategies used. Current chemical methodologies rely on a hit-and-miss approach where drugs are analyzed for their properties by hand. This process is expensive, time-consuming, and often inaccurate. This project aims to address this through the implementation of machine-learning algorithms that can predict the IC50 and pIC50 values of possible drug candidates. These values are essential in determining the quantity of a drug needed to inhibit a biological process by half but also are important in determining the toxicity of a drug and how it impacts patients. Using regression-based machine learning models and bioactivity data of compounds and target proteins, these values can be predicted. Upon completion, multiple regression models were developed for the target protein of the Covid-19. This model can be used for other target proteins for other diseases as well. After statistical analysis, the best model was chosen, optimized, and implemented: DecisionTreeRegressor. This model had a RMSE score of 0.34 and an R-squared score of 0.9019. This implies that this model fits the situation and accurately predicts. We conclude that drug discovery can become quicker, more accurate, and cost-effective through the implementation of machine learning algorithms.

Using an AI Equipped Drone for Early Detection of Fires

Ansh Hiranandani

Yujiang Zhu

The Intelligent Drone project introduces a pioneering approach to early wildfire detection, leveraging autonomous drones equipped with advanced imaging technology and AI algorithms. Aimed at addressing the critical need for timely identification of wildfires, this project is a drone capable of conducting independent surveillance over large, fire-prone areas. Through a series of tests, the drone demonstrated a 97% accuracy rate in detecting early signs of wildfires, significantly outpacing traditional detection methods in both speed and efficiency. The procedure involved programming the drone to navigate predetermined paths, capturing and analyzing images for wildfire indicators. The results display the drone's potential to revolutionize wildfire management, offering a faster, safer, and more effective detection method. This innovation not only meets the project's objectives but also sets a new standard in disaster management technology, promising substantial improvements in firefighting efforts and environmental protection.

Investigating the Impact of Oyster Aquaculture on Water Quality

Luke Okoshi-Michel

The purpose of this experiment was to assess the impact of oyster aquaculture on the water quality of Waquoit Bay . In the areas surrounding Waquoit Bay, residential development increased sharply between the 1930s and 1990s, leading to a notable increase in nitrogen discharge into the estuary, sourcing from both septic systems and fertilizers (Long & Mora, 2023). Oysters, a type of bivalve mollusk, play a crucial role in estuarine ecosystems by actively removing nitrogen and phosphorus from the water. It was hypothesized that the areas in Waquoit Bay closest to oyster farms would have improved water quality, measured by lower nitrate and phosphorus levels, and increased dissolved oxygen. Five sites around Waquoit Bay were chosen with various distances from oyster aquaculture (20m, 160m, 210m, 360m, 800m) and water samples were collected 10 times from 10/17/23 to 12/17/23. At each site, the following measurements were made, air temperature, water temperature, turbidity, salinity, and dissolved oxygen with pH, nitrate, and phosphorus measured in the lab. It was found that there was no statistical difference between the nitrate, phosphorus, and dissolved oxygen values measured at the sites closer to oyster aquaculture compared to those further away. Even though the water quality was not improved when closer to aquaculture, the average water quality at all sites was in an acceptable range. Since overall the water quality measured in Waquoit Bay was good, the oysters might be positively impacting the system as a whole.

How Does the Species of Microalgae Reduce the Effects of Carbon Dioxide in Seawater on Calcium Carbonate

Anna Li

The effect of the different species of microalgae on the mass of the calcium carbonate chalk in carbonated modified seawater was studied to identify the ability of the microalgae on reducing the detrimental effect of increased acidity resulting from elevated carbon dioxide concentrations. Based on literature research, it was hypothesized that if calcium carbonate chalk were left in four different jars of carbonated modified seawater containing Spirulina , Chlorella vulgaris, Scenedesmus quadricauda, and no microalgae for a period of 7 days, then the average percentage change in mass of the chalk will be the least after being submerged in the presence of Scenedesmus quadricauda. Calcium carbonate chalk was submerged in jars of seawater from the Atlantic Ocean that were carbonated using antacid tablets . A 10 mL sample of Spirulina, Chlorella vulgaris, and Scenedesmus quadricauda was added to each jar, and the mass of the chalk was measured before and after a period of 7 days. The least final average percentage decrease in mass of 3.37% occurred for the calcium carbonate chalk in the presence of the Spirulina microalgae, while the calcium carbonate chalk in the control group experienced the greatest final average percentage decrease in mass of 9.96%. Further experimentation on the effect of the concentration of Spirulina on the mass of the calcium carbonate showed that there was an inverse relationship between the concentration of Spirulina and percentage mass decrease. These results can be implemented in ocean acidification mitigation strategies and in further research on the utilization of photosynthetic organisms to reduce the negative effects of carbon dioxide on calcium carbonate structures.

Keywords: calcium carbonate, microalgae, ocean acidification, carbon dioxide, Spirulina, mitigation

Microplastics; A Threat Posed for Ocean Ecosystems Demonstrated by Sea Anemones

Isabella Scioletti

Nora Bruinooge

The sea anemone Aiptasia pallida, a vital component of marine ecosystems endangered by debris made of plastic, is the subject of this study's investigation into the effects of microplastics. In this experiment, feeding tongs are used to introduce microplastic particles after two to three weeks of acclimatization. The fish tanks are 20 gallons each, with one section dedicated to each type of plastic (polystyrene (PS), low density polyethylene (LDPE), and polyethylene terephthalate (PET). In order to highlight the critical need to address microplastic contamination, this experiment aims to document plastic intake and attachment. Because some anemones may have stinging cells, gloves are worn to ensure safety. Monitoring pH levels and counting plastic particles attached to anemones are two methods of gathering data. The first results show that during the course of the 8-day experiment, anemones exposed to LDPE changed in behavior and consumed more plastic. The study's conclusion includes discussions on the wider effects on marine ecosystems and the necessity of preventing microplastic pollution, highlighting the importance of legal frameworks, public awareness campaigns, and environmentally appropriate substitutes in upcoming mitigation plans.

Balance in Carbonate Convergent Waves

Michelle Chen

Bioplastics, formed following the standard bioplastic formula production process, contained varying amounts of sodium carbonate (4.6 g or 9.2 g) to investigate whether it alleviates an acidic solution differently when immersed in it for 2 hours. The 9.2 grams of sodium carbonate bioplastic was hypothesized to increase the pH of an acidic solution the greatest. The experiment utilized sodium carbonate and formed the bioplastic following the standard formula. Then, the bioplastic was immersed in the acidic solution for 2 hours, and the pH of the solution was taken at every 30-minute interval. Results showed that the 9.2-gram sodium carbonate bioplastic had the highest pH, with a 37.02% average increase. The control group– bioplastic with no sodium carbonate– had a 0.08% increase due to the lack of an alkaline substance. This data supports my hypothesis because the 9.2 grams of sodium carbonate bioplastic solution had the highest pH at the end of the 2-hour period. The results of this work could be utilized in ocean acidification enhancement processes and act as an alternative to conventional petroleum-based plastic in order to contribute to a healthier environment by decreasing plastic.

Keyword: Bioplastics, Sodium Carbonate, oH, ocean acidification, ocean acidification enhancement

A Sound Approach to Attracting or Repelling Pollinator Insects

Yvangi Jacques

Native bees are a keystone species in the ecosystem and are critical pollinators for agriculture. Given their importance to agriculture and the concern about their decline, ways of attracting bees for crop pollination or repelling bees from insecticide application areas may be useful in the ongoing attempt to protect the bees from human activity-induced decline. Numerous studies have been conducted on honey bees, but more research needs to be done on wild bees. This project investigates the novel use of sound to attract or repel bees. I investigated the effect of sound at different frequencies on the abundance of bees and other pollinator insects. In 1989, scientists William Towne and Wolfgang Kirchner discovered that bees can detect frequencies in a range of 100-500Hz. Established pollinator sampling methodology at Massasoit Community College was used to test the hypothesis that different amplified frequencies played in the vicinity of pollinator pan traps would result in an increase or decrease of bees and non-bee pollinators collected. Bee collection was done at Massasoit Community College, and a second site was at the Butler Elementary School in Avon. I tested three frequencies using a sound device I built: 100Hz, 300Hz, and 450Hz, along with bee buzzing noise. Testing occurred every ten days from mid-June 2023 to late September 2023. With my experimentation, I've discovered that pollinator insect abundance can be influenced by different frequencies of sound for individual types of insects. Some frequencies can repel, such as 300Hz for Bees and 100Hz for Wasps. Other frequencies can attract, such as 450Hz & Bee Buzzing Noise for Bees, 100Hz & 300Hz for Flies, Bee Buzzing Noise for Wasps, and 100Hz for Other Pollinator Insects. These findings may contribute to developing techniques to increase pollination or protect pollinators from insecticide applications.
Keywords: Keystone Species, Bee and Non-Bee Pollinators, Frequencies in a Range of 100-500Hz

Predictions of Massachusetts Coastal Vertebrate Biodiversity under Global Warming and Ocean Acidification Based on CMIP5 Models

Zhiyang Zhong

Global warming due to greenhouse gases (GHGs) emissions leads to environmental degradation and threatens coastal species in Massachusetts (MA), United States. However, there are limited indicators of coastal vertebrate biodiversity loss in MA or consensus on its causes. This study investigates the impact of global warming and ocean acidification on MA's coastal vertebrate biodiversity (MACVB), ultimately producing projections of MACVB under different GHGs emission scenarios in the 21st century. Based on species data in the coastal areas of MA from 1970 to 2020, the Coastal MA Living Planet Index (CMA-LPI) was constructed. The data of CMA-LPI, sea surface temperature (SST), and hydrogen ion activity (H) were examined using statistical analysis and multivariate modeling. Future projections of SST, H, and CMA-LPI by 2100 under different Representative Concentration Pathways (RCPs) - RCP2.6, RCP4.5, RCP6.0, and RCP8.5 - are obtained based on GFDL-ESM2M in the Coupled Model Intercomparison Project Phase 5 (CMIP5). The result shows negative impacts of warming SST and rising H on MACVB and H is found to pose larger threats than SST. The projected CMA-LPI losses differ based on different emission scenarios, increasing in scale from RCP2.6 to RCP8.5. Only RCP2.6 – a sustainable climate mitigation scenario– is predicted to experience a biodiversity rebound. The projection suggests that carbon emissions should be urgently reduced to mitigate global warming and MACVB loss. The study sheds light on future coastal biodiversity in MA given different GHGs emission levels, providing guidance for policymakers regarding ecosystem health and biodiversity conservation amid a warming climate.

Keywords: coastal biodiversity, sea surface temperature, hydrogen ion activity, Living Planet Index, CMIP5, RCPs

Testing Pesticide Resistance, Avoidance, and Efficacy in Mosquito Populations on Cape Cod

Molly Gedutis

Mosquito control strategies must be consistently re-evaluated as mosquito populations adapt and change. I tested the efficacy of pesticides commonly used in commercial mosquito control and private use . Results show that broad resistance has developed to adulticides, but not larvicides. I found no evidence that gravid females avoid ovipositing in larvicide-treated water and that professional-grade larvicide products greatly outperform a common store-bought product, both in the duration and magnitude of larval control. Continued use of bacterial larvicides (namely Bti) is warranted, but adulticide use should be limited to occasions of disease outbreak to avoid the development of further resistance.

Measuring Water Toxicity with Daphnia Magna

Jillian Boyle

Water pollution causes death and disease of humans and animals every day. The most common form of water pollution is runoff pollution. Some substances that often create this nonpoint source pollution include agricultural chemicals, road salt, and road sediment, which can contain chemical particles. This study aimed to discover which of these common pollutants, triazicide, road salt, or sediment, creates the largest change in heart rate of an indicator species called Daphnia magna. Daphnia magna are essential to ecosystems and their survival can indicate the successfulness of an environment. To test the hypothesis that triazicide would cause the greatest change in heart rate, Daphnia were placed in polluted water for two minutes, then transferred to a microscope slide and recorded for one minute in order to count their heart rate. Triazicide caused an increase in heart rate, while road salt and sediment caused a decrease in heart rate. The change in heart rate from the control was greatest in the road salt group and smallest in the sediment group. The collected data rejected the earlier explored hypothesis that triazicide would create the largest change in heart rate, instead showing that road salt created the largest change. To take this experiment further, the data could be used in tandem with the engineering field to develop environmentally-friendly and non-toxic replacements for common water pollutants like triazicide, road salt, and road sediment.

Decomposition of Different Bioplastics

Elmeria Cheung

Bioplastics are alternatives to plastic that are made from biological substances and are usually biodegradable. Because plastics take a significant time to decompose and essentially still exist as they only turn into microplastics, the bioplastics with a short life usage need to decompose as quickly as possible. The purpose of this experiment was to determine which type of starch would lead to the fastest decomposition rate for three different starch-based bioplastics (corn starch, potato starch, and tapioca starch). The hypothesis was if these different starches were used following the standard starch-based bioplastic formula and decomposed in compost, then compared to plastic in compost, the bioplastics would decompose more than the plastic would and the tapioca starch-based bioplastic would decompose the most. The procedure for this experiment was to make bioplastics following the standard bioplastic formula out of corn starch, potato starch, and tapioca starch. Then, the weight of the bioplastics was recorded weekly after decomposing in compost soil for eight weeks.

The results for the first data set were percent remainings of 46.6%, 45.9%, and 47.4% between the initial and final weights of corn starch, potato starch, and tapioca starch-based bioplastics respectively. The percent remaining for the results of the second and third data sets was 46.9%, 47.2%, 46.3%, 47.1%, 46.1%, and 46.9% respectively. The percent remaining for the overall averages were 46.8%, 46.5%, and 46.7%. The plastics in all three sets had 100% remaining. In conclusion, the decomposition rate of the starch-based bioplastics is not greatly impacted by the type of starch used. According to the overall average percent remaining, there was no significant difference. This is best for other industries because a concern about bioplastic is that its components would reduce the amount of starch used for other purposes, such as food. Because the results of this experiment show that the type of starch does not affect the decomposition time of starch-based bioplastics, the production of bioplastics will be able to rely on more than one source. Therefore, the types of starches would not be completely extinct but rather slightly decreased over all the types of starches to be used in bioplastic production.

Analysis and Machine Learning Modeling of Spatial Data to Identify Asthma Hotspots in Massachusetts

Thomas Li

In Massachusetts, asthma prevalence is significantly influenced by rapidly changing socioeconomic and environmental disparities. This raises the critical question: in 2023-2024, which areas of Massachusetts are most affected by asthma? We hypothesized that a Random Forest machine learning model could accurately classify geographical locations as asthma hot spots based on environmental data. To test this, we developed a model that demonstrated exceptional predictive performance, with an accuracy of 96.9%, alongside balanced precision and recall scores. This approach not only confirmed our hypothesis but also identified the key environmental factors contributing to asthma prevalence. Our findings offer a foundation for targeted public health strategies and interventions aimed at reducing asthma incidence in the most affected areas.

An Innovative Assessment of the Transgenerational Effects of Extreme Temperatures on Children's Health

Andrea Tang

Heat waves have become the #1 silent killer in the world today, driven largely by climate change. While exposures to extreme temperatures have been linked with premature deaths, there is a lack of research on the role timing of extreme temperature exposures plays on children's health, particularly during pregnancy and the first year of a child's life. My research elucidates and quantifies how environmental exposures such as extreme heat and extreme cold affect children's health through epigenetics and socioeconomic status. Epigenetics is the study of how environmental influences alter gene expression, and epigenetic changes in parents have been known to be inherited by their children. I investigate if the extent of exposure to extreme temperatures during pregnancies and the child's first year of life impacts the health outcome of children years later using data from the National Oceanic and Atmospheric Administration (NOAA) and National Survey of Children's Health (NSCH). I also examine how socioeconomic status influences the cross-generational effects of extreme temperatures on children's health. I find that the exposure to extreme temperatures during mothers' 9-month pregnancy window and the first year of their children's lives significantly increases the likelihood and frequency of hospital emergency room visits for the children later in their lives, with p-values less than 0.05. These findings are consistent with the conjecture that there are cross-generational effects of temperature exposures on health through epigenetic mechanisms. Furthermore, extreme temperatures more strongly shape the health of children whose families rely on food stamps, free or reduced cost school meals, and cash assistance from the government, leading to promising key public policy implications.
Keywords: climate change, extreme temperatures, epigenetics, health, socioeconomic status, policy

Optimizing UV-C Photosynthesis: Accelerating Crop Growth for Global Food Security

Grace Gunning

Sophia Salinas

We propose a method to enhance plant growth and eliminate pathogens by incorporating UV-C radiation as a plant cultivation method in timed intervals. The evolution of our method was broken into two trials, with seven days in each. Trial 1 was focused on testing our hypothesis, as we exposed our UV-C plants to 3 intervals of five-minute UV-C light exposure. We assessed all our molecular data points using a spectrophotometer, which gave the plant's chlorophyll and nitrogen levels used to prove our hypothesis. Our three plant variants were chosen based on their accessibility to us and were split into two groups: newly sprouted plants and a month-old plant. In doing this, we first exposed our newly sprouted chia and bean sprouts to three intervals of five minutes. Two days after our newly sprouted plants were exposed to UV-C light, we incorporated month-old store-bought Spearpoint Ivy plants. The molecular data points in Trial 1 are for our Spearpoint Ivy plants, which we separated into control and UV-C groups. Toward the end of trial one, we noticed that our chia control group's water had a foggy layer over it while our chia UV-C group's water had a clear yellowish hue.

Recognizing this as a possible thing to refine for our UV-C method, we lessened Trial 2's UV-C exposure time to two intervals of five minutes. In Trial 2, we did not include our chia plant variants as they did not sprout properly. Our Trial 2 data points mainly assess the physiological and molecular changes of our Spearpoint Ivy plants. The physiological changes of our bean sprouts and Spearpoint Ivy plants were only included in Trial 2 as we anticipated more noticeable physiological changes. Both molecular assessments for Trials 1 and 2 showed increased Spearpoint Ivy UV-C's chlorophyll and nitrogen levels. Our plants' chlorophyll and nitrogen levels were used as data points to contribute to our hypothesis. We could determine the significance of our chlorophyll results using a statistical data analysis test called the T . test. This test suggested all chlorophyll and nitrogen levels were significant except for Trial 2's nitrogen levels, which were not included. The physiological data points were also taken from Trial 2 bean and Spearpoint Ivy leaves, which said our Control Bean stems were slightly longer than our UV-C beans, and the UV-C Spearpoint Ivy leaves were much wider than their control. This proved our hypothesis as we saw no negative or drastic effects of UV-C light on plant growth. We want this method to be used in large-scale crop production to innovate UV-C light towards a more nutritional and accessible world.

Zero Emission Cooking

Alvira Nair

Indoor air pollution and respiratory issues are prevalent in our community. A growing number of studies analyzing the link between children's respiratory illnesses and poor indoor air quality from natural gas cooking stoves at home prompts discussions for strict regulations and a bill proposing changes to building codes, including a ban on gas stoves in new constructions. Despite causing turmoil among politicians and the public, the bill aims to improve indoor air quality and, hence, people's health. Inspired by this, I hypothesized that natural gas stoves deteriorate indoor air quality, leading to health issues. Measurements using handheld gas detectors for various cooking devices like gas stoves, gas ovens, electric stoves, and induction cookers revealed high carbon dioxide emissions from natural gas stoves but no other combustion contaminants.

However, data collected from representative homes showed no correlation between pediatric asthma rates (MEPT) and indoor air quality. My study did not establish a clear link between pediatric asthma and indoor air pollution, which partially rejected my hypothesis.

Urbanizations Effect on Microplastics in Massachusetts Beaches

Claire Seguin

Emma Andacic

Paulina Kirik

This project aimed to investigate the correlation between urbanization levels and microplastic contamination in Massachusetts beaches. The central question addressed whether beaches in more urbanized areas would exhibit higher levels of microplastics compared to less urbanized ones. Utilizing a comparative approach, samples were collected from five beaches varying in urbanization levels, ranging from rural reservations like Crane Beach, to urban locales like L Street Beach. Through meticulous extraction techniques involving water and sifting, microplastics were isolated from the sand samples. Analysis revealed a significant statistical correlation between the degree of urbanization and microplastic presence, supporting the hypothesis. This underscores the direct influence of urbanization on microplastic contamination in coastal areas. Future investigations could employ microscopic analysis for enhanced accuracy, considering the limitations of naked-eye observation. Moreover, exploring the sources and pathways of microplastic contamination, as well as its ecological impacts, could provide valuable insights for mitigating this environmental issue.

Littleton Water Quality Study

Finley Pletcher

Finn Canning

The purpose of this project was to determine if pollutants in bodies of water were seeping into household wells and therefore getting into people's drinking water. This project was done to keep the people of Littleton informed and safe. Water is a universal solvent, meaning many different substances can dissolve in it. In a well, pollutants can seep through from the groundwater (Water Science School, 2018). To test this, samples of water were gathered from 30 different bodies of water in Littleton, along with several different wells, and then tested for 15 different pollutants (nitrate, nitrite, hardness, free chlorine, total chlorine, bromine, MPS, copper, iron, lead, nickel, sulfite, cyanuric acid, carbonate, and hydrocarbons). The bodies of water and the wells that were nearby were clustered into six different groups based on proximity to one another . An ANOVA was first performed and revealed that there was a significant difference between the measurements in all the bodies of water and all the wells. Next, Pearson's correlation coefficient test was performed for each cluster for each of the 6 most common pollutants, to see if there was a correlation between the levels of pollutants in the bodies of water and in the well water. The results showed that there was no relationship between the levels of nitrate and carbonate in the bodies of water and the levels in the wells. The level of lead in the bodies of water had a moderate positive correlation with the level in the wells, but these results were not statistically significant. The levels of copper and nickel both had moderate to strong negative correlation between the bodies of water and the wells, but these results were also not statistically significant. Finally, the hardness level in the bodies of water and that in the wells had a statistically significant strongly negative correlation. One limitation that could explain the negative correlations for nickel, copper, and hardness is that the households with wells could have a filter which removed the excess particulates. Further research would involve gathering more water samples closer together, along with involving multiple close-by towns in order to increase the number of clusters for analysis.

The Effect of Fire on the Amount of Chlorophyll in Pine Tree Needles

Qinghe Zhao

Chlorophyll is the natural green pigment that plants require for the process of photosynthesis. This project is about how fire burning can affect the chlorophyll content of pine tree needles. According to previous research, the chlorophyll content can be higher for marsh land plants and post-fire re-sprouting of woody plants in burnt land areas. The experiment conducted in this project extracts chlorophyll from pine tree needles in fire condition and not in fire condition and measures the peak absorbance of (orange) light to determine the chlorophyll concentration in each pine tree needle sample. The result shows that the average concentration of chlorophyll in pine tree needles is approximately 1.3 higher for pine trees that are affected by fire burning, which has an average chlorophyll concentration of 3.022, than pine trees that are not affected by fire burning, which has an average chlorophyll concentration of 1.725. This result corresponds to previous research on marsh burning and post-fire re-sprouting of woody plants, and shows that fire burning can also increase the chlorophyll content in pine tree needles. Higher chlorophyll content in pine tree needles can increase the rate of photosynthesis in pine trees, and they are able to obtain more energy to grow healthily and live longer. In addition, there can be more exchanges of carbon dioxide and oxygen occurring from a higher photosynthesis rate in pine trees, and they can decrease the amount of carbon dioxide and greenhouse gas in the air to help solve climate change.

The Efficacy of Duckweed in Mitigating Per- and Polyfluoroalkyl Substances (PFA/PFOS) on Daphnia Magna

Chelsea Bateman

The goal of my project was to determine if duckweed was able to mitigate the effects of PFAs and PFOS on the small freshwater invertebrate, daphnia magna. My hypothesis was that duckweed would be able to lessen the damage caused by Per- and Polyfluoroalkyl Substances on daphnia. To test my hypothesis, I set up 12 pyrex dishes of daphnia - 3 with duckweed and water containing PFAs, 3 with duckweed and water free of PFAs, 3 with no duckweed and PFA water, and 3 with no duckweed and no PFA water. I kept every other variable the same to see whether the daphnia populations in the habitats with duckweed and PFAs showed a significant difference to those with no duckweed. My experimental process ran smoothly, and after analyzing my results, I found that the null hypothesis was supported. However, though my independent t test yielded no significant difference between the duckweed variable, the presence of PFAs and PFOS were very impactful to the daphnia populations. There was a strong significant difference in population between dishes with PFA and PFOS contaminated water and clean water. In fact, there were only two living daphnia found throughout the six contaminated water habitats - one in a duckweed environment and one not. In the non-PFA/PFOS habitats, there was evidence of reproduction in the two week long experimental process, averaging 59 daphnia per dish. I can infer that the daphnia's survival and reproduction rate had to do with the effects of per- and polyfluoroalkyl substances have on reproduction and lifespan of daphnia.

Heavy Metal Analysis of Lichen Samples at Lower Neponset River Reveals Previously Overlooked Contamination

Yuxuan Zhang

The lichen Flavoparmelia caperata is recognized as an effective bioaccumulator and bio-indicator for monitoring heavy metal pollution, offering insights into early environmental changes worldwide. This research focuses on the Mother Brook Confluence, a segment of the Lower Neponset River, MA, which has been relatively understudied for heavy metal contamination. The study involved a comprehensive survey of all trees within the selected area of Mother Brook Confluence. Among the diverse lichen population identified, samples of Flavoparmelia caperata were collected from 88 unique trees that meet specific criteria. 48 samples were selected for detailed analysis. The concentration of 19 trace metals (Ag, Ba, Be, Cd, Co, etc.) was measured using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) at the University of Massachusetts Lowell. The analysis revealed significantly elevated concentrations of Selenium (Se) and Lead (Pb), at 4.615±2.503 ppm and 29.430±25.005 ppm respectively, compared to background levels reported in previous studies. The spatial distribution of these metals indicated three potential contamination hotspots for each Se and Pb. These findings underscore the utility of Flavoparmelia caperata as a reliable bio-accumulator for detecting environmental changes, particularly in the context of heavy metal pollution.

The Effects of LED Lighting on Painted Lady Butterflies

Kaitlynn Goulette

Light pollution is an issue across the entire world and can potentially be very dangerous. The purpose of this science fair experiment is to better understand the physical side effects of light pollution. To do this, research was done on the characteristics of light and vertebrates. Painted lady butterflies were chosen for this experiment separated by fives in five different groups. Raised from larvae, each group was exposed to LED lighting for a different time period per day. When they bred, their offspring were supposed to be counted with those who were exposed to LED lighting 24 hours per day producing more than those who were not exposed to LED lighting. Unfortunately, no offspring were produced. After further research was completed, a few viable explanations were that the male-to-female ratio was off, the cages were too small, and there was no host plant. Next year, I will have larger cages and more butterflies in each group, with there being only four groups in total instead of the original five. Also, I will raise a batch of butterflies without focusing on the light exposure to better learn how they thrive and survive before beginning next year's experiment.

A Study of Natural Plastic Biodegradation by Polyphenol Oxidation Using Galleria mellonella

Arohan Pathak

Siddarth Padamati

Plastic pollution, a significant cause of much damage to ecosystems, has a great impact and influence on the environment, especially in today's world. The amount of plastic has continued to increase significantly. It is a major waste product annually producing 400 million tonnes (Lai & Kneefel, 2023). Toxic compounds from plastic have continued to harm the environment, and ongoing plastic production demands the use of larger amounts of fossil fuels. A novel solution to reduce the toxic effects of plastic is the use of biodegradation to help mitigate the harmful aspects of plastics in the environment . This project used wax worms, Galleria mellonella, which have a natural enzyme called phenoloxidase in their saliva which can be used to break down the plastic. The experiment investigated and analyzed the results comparing wax worms with and without food to see how effective this method was at degrading plastic in an environmentally friendly way . It was hypothesized that the Galleria mellonella group with both plastic bags and extra food would destroy the plastic polymer at a faster rate than the group with only plastic bags. The hypothesis was supported; the experimental group with food and plastic had the highest average mass decrease in plastic over the five weeks, suggesting that plastic degradation is possible in a natural way. Future research can find ways to isolate and use phenol oxidase to naturally break down plastic.

Correlations Between Chemical Composition of Water and Soil with Biodiversity in Urban Bodies of Freshwater

Alexis Solis

The US has become significantly more urban over the past decade. The exponential urbanization of the US has a strong impact on the environment and the multitude of ecosystems that make up nature. Making sure that freshwater ecosystems are regulated is important when considering their significance to the survival of mankind and many other species.This study investigates the chemical composition and urbanity of fresh bodies of water and how it can be related with the biodiversity of the bodies of water. In total, 6 different ponds throughout the state of Massachusetts were included in this study. From each location there were 2 water samples and 1 soil sample. The water samples were tested using a pond testing kit and the soil samples were tested using a soil test kit. Each sample of water had 4 singular drops observed into a microscope where the average biodiversity value (BDV) for each location was then determined using a scaling system. When determining the urbanity, the population density of the town that the pond was found in was used as a numerical value. This experiment did not show a connection between the urbanity of the location with neither the chemical composition of the water and soil nor the BDV of the sample. Instead this experiment helped showcase which chemical values of the water and soil were best for a higher BDV value in bodies of freshwater.

Assessing the Feasibility of Dawsonite Production as a Carbon Sequestration Strategy

Disha Mudenur

Rylee Blair

Ocean Acidification will cause the collapse of entire marine ecosystems. To combat ocean acidification, an original procedure with electrolysis on ocean water using dawsonite as the CO2 acceptor was created. The Dawsonite Diver, a one-of-a-kind carbon sequestration machine that executes the procedure, was built. If implemented on the 11 million yearly cargoship trips, 200,000 metric tons of oceanic CO2 would be removed, so verifying the composition of the compound, dawsonite is vital to slowing ocean acidification. Four phases of experiments were carried out to prove that the mineral created (the unknown precipitate, UP) as a result of the procedure was dawsonite and not an ordinary salt: crystallography, solubility, fire retardant, and crystal structure.

Running the powder UP in an x-ray diffraction machine at 100K and 2 theta, the resulting diffractogram was compared to existing dawsonite and NaCl diffractograms. While the majority of peaks and intensities on the UP matched the Dawsonite diffractogram, minor discrepancies arose since a powder sample was used rather than the typical crystal.

Since dawsonite dissolves incongruently in water, but congruently in HCO3(aq)-, and NaCl dissolves completely in water, 1 gram of UP was dissolved in both solutions, and 1 gram of NaCl was dissolved in water. While NaCl and UP in HCO3(aq)- showed >1% residue, UP in water showed 20% residue.

While salt is used in food, dawsonite is used as a fire retardant. A flame was lit, and 1 gram of each precipitate was sprinkled on the wick, with the time of flame extinguishing being measured. The UP extinguished the flame statistically faster than the NaCl.

Crystals were created by oversaturating a water and HCO3(aq)- solution with respective precipitates and allowing crystal formation along a string over two weeks. The UP was seen to display an orthorhombic dipyramidal shape under a microscopic, which is typical of Dawsonite. The NaCl was seen to display a cubical shape.

Algae Fertilizer: Efficiency and Biosorption of Copper by Chlorella Vulgaris

Juliet Findlen

By replacing traditional chemical fertilizer, algae fertilizer can help reduce the environmental impact of farming, such as algae blooms due to runoff contamination, through nutrient slow-release mechanisms, longer application periods, and increased nutrient diversity in soil. Algae strains such as chlorella vulgaris have properties of biosorption, in which heavy metal ions can bind to cell walls, a mechanism that has proved useful for treating heavy metal contamination in water, and has been postulated to have a positive effect on plant growth when applied in environments with heavy metal contamination . Experimentation showed that algae fertilizer was initially equally effective as chemical fertilizer when applied according to the industrial fertilizer standard (as a percentage of nitrogen by mass), although larger quantities were used to achieve that result. Algae fertilizer also promoted a longer period of heightened growth than chemical fertilizers. When exposed to high concentrations of copper contamination in soil, algae fertilizer did not have a significant impact on the growth rate of grass, but did decrease the presence of stress responses in the plants, such as the percentage of plants going to seed. Algae fertilizer also did not have a significant impact on the concentration of copper in runoff from contaminated soil . It should be noted that the algae fertilizer did have a small positive effect on increasing plant growth and decreasing copper concentrations in runoff, although not a statistically significant one, possibly due to the disproportionate amount of algae and copper used, indicating that algae may be helpful when copper contamination is less severe.

Absorbing CO2 Using Moss

Jonas Miller

This project's goal is to find an efficient way to control the amount of CO2 in the air using moss sequestration abilities, building upon existing knowledge of this topic. One species of moss used in this experiment, Sphagnum, is known for being the best genus of plant at CO2 sequestration, and using it in this experiment can help support that theory. Using current research that shows moss's excellent carbon storage, this project tests 5 types of commonly found moss to see which species absorbs the most CO2.

The testing portion of the experiment spanned 5 weeks: 1 week per moss type. Using an airtight jar with a CO2 monitor inside, the CO2 levels were measured and recorded each day. After the 5 weeks were over, the data was analyzed through a line graph, and compared to each of the other mosses.

The moss type that decreased the most throughout the experiment was Hypnum Curvifolium, showing a notable decrease of 642 ppm. Though Sphagnum Moss did end with the lowest amount of CO2, it did not decrease the most, meaning the hypothesis was not supported.

Throughout the experiment, a noticeable pattern was shown in the fluctuation of CO2 levels. An initial increase occurred on the first day of testing with every moss, and on the 5th and 6th days, the data showed a decrease in CO2. With the danger of global warming and climate change ahead, the results of this experiment could be very beneficial to the future of society. Not only will it shine a light on the importance of moss for controlling CO2 levels, but overall lowering the levels in areas of the world, especially in highly polluted cities by integrating it into urban architecture.

Analyzing Amplitude Contrast in Water Containing Different Salinity Concentrations

Victoria D'Aiello

To investigate the hypothesis, in cases where water contains lower concentrations of salt (NaCl), sounds conducted under the water's surface will have a higher amplitude (in dB) compared to areas with higher concentrations of salt. Through two test groups, control and experimental, as well as conducting 30 trials for both groups, the results accepted the proposed hypothesis. To actually test sound conductivity underwater, a large container had to be obtained and filled with enough salt water to mimic the natural salinity of the Arctic Ocean. With a waterproof bluetooth speaker and homemade hydrophone, a short sound clip was played and recorded onto Audacity, where the amplitude was documented and saved for further analysis.

Knee Deep in Physics: What Angle of the Knee Puts the Most Strain on the Patellar Tendon?

Cassandra White

The purpose of this experiment is to see what angle of the knee puts the most strain on the patellar tendon . This intrigued me because I injured my knee two and a half years ago and it still bothers me to this day. This experiment could be helpful in seeing what irritates the knee and why. Knowledge of the knee can not only help me but also others with knee sprains, strains, fractures, tears, etc. My hypothesis was that if the knee is bent more, then there will be more strain on the knee, because it adds more tension. This was proved correct by my experiment in which I made a model of the knee and tested the strain on it by measuring the length of a spring, representing the patellar tendon, made by various angles of the knee (30, 60 and 90 degrees). I found which angle led to a greater strain by subtracting the length of the spring without any strain from the average length of the spring at each angle. The greater the number that resulted, the greater the strain. As expected the smaller the angle, meaning the greater the bend of the knee, the more strain there was. At 90 degrees the spring length only increased by 0.125 inches, while when the model knee was bent to a 30 degree angle the spring length increased by around 0.292 inches, meaning there was more strain at 30 degrees, the smallest angle, than at 90 degrees, the biggest angle tested.

Insights Derived from Benchmarking Viral Antibody-Antigen Structural Complexes Against General Protein-Protein Interactions

Kenny Wong

Viral antibody–antigen (Ab-Ag) interactions serve as our frontline defense against viral infections where antibodies recognize and bind to viral antigens, resulting in neutralization. The field of antibody engineering seeks to better understand viral Ab-Ag binding, but experimental work in this area suffers from extensive resource requirements, biosafety concerns, and reproducibility issues, making computational approaches a necessary alternative. Indeed, antibody-related computational analyses based on various sequence databases such as DIGIT, IMGT, abYsis, Antibodypedia, and the Antibody Registry have yielded fruitful results. However, to get a better understanding of the antibody response, we must look beyond the sequence space and consider the molecular nuances of viral Ab-Ag interactions by examining structural data. Here, we curated a structural dataset of viral Ab-Ag interactions and benchmarked them against general protein-protein interactions. Our physical benchmarks include the number of residual contacts between antibody and antigen chains, hydrogen bonding, secondary structure composition, binding interface surface area, and binding energy. Our results reveal that viral Ab-Ag interactions have significantly less variation in terms of those physical features. Additionally, various dimensionality reduction techniques in the conformational space show that viral Ab-Ag interactions are structurally distinct from general protein-protein interactions. Insights gained from these benchmarks and analyses can help researchers identify conserved structural motifs that are crucial for efficacious vaccine development.

Heart to Heart: 3D Mitral Valve Repair Modeling

Sarah Job

Xuemei Qu

Mitral regurgitation (MR) affects more than 4 million people in the United States and the European Union and its prevalence increases with age, reaching up to 1 in 10 adults aged 75 years or older . While mitral stenosis (MS) is less common, affecting only 1 out of every 100,000 people in the U.S, MS is common in developing countries where there is limited access to antibiotics and medical care. As the incidence of heart disease rises globally, understanding the mechanisms underlying mitral valve dysfunction is becoming increasingly crucial for developing effective treatments . When the mitral valve leaflets fail to close tightly, blood regurgitation occurs, leading to backflow and impaired heart function, posing a significant challenge to heart function. Conversely, mitral stenosis occurs when the valve opening narrows, forcing the heart to pump blood through the restricted channel harder. This STEM Fair project aimed to explore which material and configuration would be best when simulating and studying mitral valve replacements. Multiple models were designed and tested throughout this project in search of finding the answer. This project conducted flow studies using a mock circulatory system to simulate physiological conditions and evaluate the valve's hemodynamic performance . Through iterative refinement of the model and analysis of functional feedback, the feasibility of the model was assessed.

Your Voice Matters: Using Machine Learning to Detect and Classify Dysphonia

Atreya Mallanna

Vivek Mehta

Vocal disorders are a broad range of conditions that lead to a change in how the voice sounds , mainly due to the improper vibration of the vocal cords. Current methods to detect vocal disorders are invasive, time-consuming, and costly. In order to mitigate these problems, this project focused on a method in which users could easily record an audio sample such as .wav or .mp3. Given the rise in popularity of Artificial Intelligence (AI) and Machine Learning (ML), there are a plethora of tools available for the public to utilize. This project presents a ML model that identifies the potential presence of a vocal disorder. The model accurately classifies the presence of a vocal disorder around 90% of the time, with minimal apparent bias and overfitting. Furthermore, if the individual is detected to have a disorder, the model determines the most likely diagnosis between three prevalent voice disorders: laryngitis, muscle tension dysphonia, and vocal cord paralysis. Our model relies on the conversion of raw audio data to an image form via a series of transformations including Short Time Fourier Transforms, logarithmic unit conversions, raw audio augmentations, and spectrogram augmentations. Utilizing three Convolutional Neural Networks (CNNs), the model tries to classify and predict the outcome of a given raw audio input. Our training dataset included around 100 healthy and pathological samples each, from the Saarbrucken Voice Database (SVD) and the Perceptual Voice Qualities Database (PVQD).

Key Words: Vocal disorders, Vocal cords, Machine Learning, Laryngitis, Muscle Tension Dysphonia, Vocal Cord Paralysis, Spectrograms, Convolutional Neural Network (CNN), Machine Learning (ML), Audio Augmentation

Predictive Analysis of Sjögren's Syndrome: A Machine Learning Approach

Aaryan Arora

Madhav Girish

Sjögren's Syndrome (SS) is a chronic autoimmune disorder affecting moisture-producing glands, impacting an estimated three to four million people in the United States. SS presents significant challenges due to its complex symptoms and difficult diagnosis. Despite its widespread impact, it remains understudied. This study addresses two primary issues: the elusive understanding of its etiology and its unreliable diagnostic methods. Through a population-based study involving 34,000 individuals and statistical analysis using Pearson's correlation coefficient, significant correlations were found. A positive correlation emerged between parental joint pain/dry eyes and the incidence of Sjögren's Syndrome in offspring, alongside an inverse correlation between cigarette use and SS likelihood, indicating potential hereditary links and protective effects of smoking. To tackle diagnostic challenges, two models were developed. A preliminary risk classifier identified 85% of SS cases based on patient symptoms, while an SS diagnosis model using CT scan images achieved 98.76% accuracy, 95.6% sensitivity, and 93.0% specificity. This model not only accurately classifies SS but also localizes anomalous areas through a heatmap, providing detailed insights into disease manifestations. Furthermore, a backend system was developed to flag patients at risk of SS based on recorded symptoms from routine check-up exams. Additionally, the CT scan classification model, with its heatmap visualization, was seamlessly integrated into a user-friendly graphical interface for easy image analysis in clinical settings. This comprehensive approach addresses crucial gaps in SS research and diagnosis, offering valuable insights and practical solutions to improve patient care and outcomes.

OncoGPT: An AI Assistant for Genomic-Driven Precision Oncology

Samuel Ding

Background: Each cancer patient's genomic profile is unique, and the treatment should be individualized. High throughput next-generation sequencing (NGS) technology allows us to identify all genomic alterations within a patient's tumor tissue and blood-circulating tumor DNA (ctDNA) in a single test. A patient's unique genomic profile can help oncologists select a course of precise personalized treatment for the subject.

Methods: OncoGPT was built on a cloud-based elastic computing platform. The NGS data analytical module comprises a cascade of computational algorithms for NGS data processing and gene variant calling. The interactive and univariate Cox proportional hazards models were used for mutation-treatment matching and prognostic effect analysis, respectively. Machine learning algorithms including decision tree, random forest, and neural networks were trained and tested for tissue-of-origin (TO) classification across 8 cancer types.

Results: We built an AI-driven NGS data analytical platform by integrating computational models, matching algorithms, and variant annotation databases to highly accurately achieve cancer-related gene mutations, copy number variation (CNV), and structure variants using NGS data from 35,122 tumors across 8 cancer types from three institutions. Next, an AI-driven TO classifier was developed, achieving a weighted F1 score of 0.926 for high-confidence predictions (≥ 0.9) on tumor samples. Furthermore, augmented AI matching algorithms were applied to match the optimal personalized treatment, and provide a prognostic prediction for cancer patients (hazard ratio (HR) = 0.326; 95% confidence interval (CI) = 0.213–0.565; P = 2.52×10−5).

Conclusions: We have successfully developed an innovative software system (OncoGPT) with AI capabilities to help accurately find actionable targets from patient tumor or blood ctDNA NGS sequencing data and precisely match individualized therapeutic and clinical trial options for patients. We believe that OncoGPT would help clinicians make optimal treatment decisions for cancer patients through genomic-driven precision oncology.

Advancing PTSD Research with Machine Learning: Rapid Regression-Based Screening of Novel Corticotropin-Releasing Hormone Receptor 1 Antagonists

Candice Lin

Eric Li

Lucy Wei

A focus of previous studies to develop a treatment for the development of PTSD symptoms has been the hormone CRH, which plays a crucial role in the regulation of the HPA axis, a primary stress response system. Elevated CRH levels in subjects with PTSD cause a blunted ACTH response, leading to the dysregulation of the HPA axis. Attempts to address this blunted response by developing effective antagonists for the CRH type 1 receptor and thereby preventing the receptor's blunted response have been unsuccessful until recently. In an effort to accelerate the discovery of novel CRHR1 antagonists, we have developed a simple and accessible machine-learning model for the rapid screening of candidate ligands based on calculated molecular descriptors. Our multiple linear regression model, trained and optimized on simulated docking data from a dataset of 228 selected molecules, achieved a mean absolute percentage error of 9% and an R-squared value of 0.7145, indicating accuracy within the training set and moderately strong correlation when tested against unknown data points. The model isolated 25 unique attributes as most strongly correlated with the performance of a novel candidate molecule. The model's design was validated using 10-fold cross-validation. Our implementation is also easily exported to other biological pathways of interest, lowering the barrier to entry for research into novel treatments for a wide array of diseases and hopefully accelerating medical research into niche and otherwise cost-prohibitive treatments.

Engineering a Termination Readthrough-Based Gene Switch Enables Controllable CRISPR Gene Editing

Yifan Evan Ding

Gene switches that can artificially regulate gene expression are in high demand for developing safe and effective gene therapies. Using in vitro cell culture, DNA transfection, and fluorescence microscopy, I first examined the efficiencies of the three stop codons in terminating protein translation. I found that all three stop codons were “leaky” albeit at low levels and could be subject to termination readthrough. By exploring drug dependency of stop codon readthrough, I constructed a new two-component gene switch that consisted of a 9-nucleotide, TGA-comprised DNA effector, and a chemical inducer (US patent application filed). The DNA effector was designed to be inserted into the target gene of interest and to limit gene expression using the native function of the stop codon TGA. The chemical inducer, such as the clinically available gentamicin, would be applied separately to increase readthrough of TGA, thereby “switching on” target gene expression. I validated the design of such gene switch by observing its function in controlling Cre recombination in vitro. Importantly, I further demonstrated the feasibility of using this gene switch to engineer “switchable” CRISPR-Cas9 gene editing machinery that could have potential for clinical use. The extremely small size of the DNA effector, low risk of immunogenicity, and clinical track record of the chemical inducer make the gene switch I reported herein a potentially versatile tool for developing inducible cell and gene therapies.

Designing an Economical Multi-Purpose Care Blanket for Neonates Continuation

Luke Bulan

This project is a result of research conducted on premature babies and their health risks , especially those involving temperature regulation. The importance of direct parental contact and the closed- off nature of developmental incubators made for a poor combination that called for a blanket to be made to cut the separation between parent and child. This blanket would look to incorporate many different aspects of neonatal care simultaneously and optimally .

A heating pad and blue LED lights were sewn into a swaddle blanket . The irradiance of the lights would be tested one time to ensure they matched the intensity of that from the previous model's lights . Trials would be run with the heating component on, and it would be controlled manually to keep it consistently within the range of an infant's average body temperature of 36-38°C. A digital thermometer would be used to periodically check the temperature over a long period of time.

In a two hour trial, the temperature remained relatively consistent with active control of the heating component. Out of every 5 minute interval in the trial, temperature never varied any more than 2.5°C out of the optimal range, and it was found that adjusting the heat setting would work quickly and reliably bring the blanket back within safe range. It was found that on average, controlling the temperature manually would provide an average temperature of 37°C, right in the middle of the comfortable range required for success. While there were some flaws in the trial as a whole, the broad look of the data is a sign of success, and being on the right path toward the desired final design.

The further development of this model could mean a massive societal impact . An all-encompassing, cost-efficient, fully-effective, safe and comfortable swaddle blanket for neonates with health issues could completely change the scene in NICUs and homes across the world. By incorporating more features to make the blanket a true catch-all of treatments for potential health risks, more space could be left in NICUs for those most in need of intense care. Babies who just need stricter conditions as they develop into healthy infancy could be cared for at home with little risk.

A Two-degree Freedom Servo Driven and Scoliosis Angle Adaptive Rehabilitation Chair

Leyi Su

Spinal Cord Injury (SCI) significantly impacts patients, requiring extensive rehabilitation or surgery for severe cases. China reports over a million SCI cases, with 10,000 to 60,000 new instances annually. Current technology cannot resolve the neural disconnection between the spinal cord and human brain. However, neuroplasticity can be activated through effective physical rehabilitation for patients with incomplete spinal cord injury. The invented rehabilitation equipment can only fit in the use within the rehabilitation center under the supervision of the professionals. This design is time-costly for post-surgical patients and patients with less damage to their spinal cord since they also require frequent rehabilitation exercise to activate their neuroplasticity. This project aims to develop a more interactive and convenient rehabilitation device to improve the rehabilitation experience of a particular group of patients. It aids patients in back exercises, enhancing control over waist movements in two dimensions: backward-forward and leftward-rightward. The use of linear actuator, servo-driven gear system, torque sensors, bluetooth wireless control, and other electronic devices will help in accomplishment of that. They allow the rehabilitation chair to provide accurate movement, real time feedback of the force-bearing status, and wireless control on a smart device. The design leverages the flexibility of quadrilaterals and the stability of triangles to support the patient's back rehabilitation effectively. Different from rehabilitation apparatus design for fixation purposes, this design of post-SCI-surgery rehabilitation chair allows the patients themselves to adjust the movement range of the back brace. According to the experiment, this rehabilitation chair can support a 60-degree left-right and back-front movement range for patients. The first generation showed a great accuracy on the left-right movement but bad load-bearing capability and inflexible transformation of the shape of the back brace to meet the need of different users. The second generation not only addressed the problems in the first generation, but also constructed a more balanced structure with effective numerical feedback value. The analog curve testing indicates the relationship between the analog signal demonstration and the force the chair bears. The displacement deviation test explores the accuracy of the rotation of the back brace from two degrees of freedom by calculating the deviation from the actual displacement angle to the theoretical displacement angle. After the construction of two generations of prototype, the prototype accomplished a self-adaptive structure to meet the need of different populations and the convenient bluetooth smart controlling system, while the visualization of patients' daily training progress could be finalized in future studies.

Artificial Endocrine System

Dashiell Hanson

Jake Zink

Nathan Julia

Students at Lowell High used an arduino board, electronic components, and water pumps to model the function of an endocrine gland like the pancreas in the human body. The arduino board uses a negative feedback loop to return the conductivity of the water to a set value. This imitates how the pancreas is able to monitor blood glucose levels in the body through similar negative feedback loops. The data collected shows that, while initial models struggled to collect accurate conductivity values and turn pumps off at the right times, the most recent model was able to successfully bring the conductivity of the water down to the right level. However, it was found that the pump for adding tap water was too weak, which means that in future models, a replacement will be needed. Additionally, the code could be cleaned up by finding an alternative solution to using nested if-then statements.

Multi-Step Meta-Analysis of Multiple Human Genome-Wide-Association-Studies to Uncover Highest Risk SNPs Associated with Coronary Artery Disease, Type II Diabetes, and Alzheimer's Disease

Angad Pannu

Type II Diabetes, Alzheimer's Disease, and Coronary Artery Disease are just three of many major conditions which severely hinder our bodily functions. About 1 in 10 Americans are affected by diabetes, 90% of which are Type II. An estimated 6.2 million Americans aged 65 and older are currently living with Alzheimer's disease, a number projected to reach 12.7 million by the year 2050, while Coronary Artery Disease is the leading cause of death in the United States. Moreover, these diseases are multifactorial, as both environmental and genetic predispositions contribute to the development of these diseases. While the environmental component has been thoroughly researched, it is time to turn our attention to the genetic factors of these conditions. Although individual genome-wide-association-studies have identified risk SNPs for these conditions, the GWAS conclusions lack a unifying synthesis of all current research, as well as diversity among significant GWAS results. Thus, it is difficult for researchers, physicians, and patients to understand which individuals might be inherently at risk of developing these debilitating diseases, which delays preventative treatment measures. Researchers are also lacking clear direction for future research into specific dysfunctional genetic pathways that might be responsible for disease development.

There is a need for a synthesizing data analysis tool which will combine the final data sets of disease-specific GWAS', and will identify the highest risk SNPs that are associated with disease development; this will not only shape treatment plans in the future, but will also pave the way towards the development of precision medicine, earlier preventative measures of disease onset, and perhaps novel cures for virtually any disease.

In this project, 283,938,472 SNPs were strategically filtered using a sequence of data-analysis techniques. The data was first pre-processed into an R Program, then inputted into the META-Metal Analysis software. Post Meta-Analysis processing was done using a separate R Program, preparing the data for visualization. The input was visualized and authenticated using FUMA GWAS, while the final correlation analysis and G-DARE was created using the software Tableau. Overall, the engineering goal was clearly met, as this project created a multistep method of statistical meta-analysis which synthesizes SNPs from a variety of studies, and refines them to statistically significant and high impact SNPs. This highlights significant genetic polymorphisms associated with the aforementioned diseases. This approach will not only identify polymorphisms which predispose patients to disease, but also uncovers correlations between different diseases and common SNPs, highlighting shared genetic pathways. This approach culminated into G-DARE, a cloud available tool available to both researchers and the medical community.

This innovation has the potential to aid physicians in identifying individuals who are more susceptible to any disease, streamlining the process to delay or minimize the onset of these diseases with lifestyle changes. This method is a big step for researchers, serving as a stepping stone towards investigating correlations and genetic pathways between numerous diseases.

BiliSpectro: Building and Testing a Noninvasive Optical Sensor to Detect Bilirubin Content in Blood for Diagnosis and Monitoring of Jaundice

Jacob Wu

Shrila Maity

Jaundice, a dangerous condition impacting 80 million infants annually, arises from excessive bilirubin in the bloodstream, potentially causing brain damage, disability, and death. The current testing standard, the Total Serum Bilirubin blood test (TsB) is invasive and must be continually repeated during treatment, increasing the risk of anemia, worsening jaundice, and cardiac arrest. The noninvasive alternatives, transcutaneous bilirubinometers (TcB) are frequently inaccurate and costly. This project aims to develop an accurate, practical, and affordable device to noninvasively detect and monitor bilirubin levels, reducing the need for invasive blood tests. The device accurately isolates bilirubin and hemoglobin absorbance using spectrophotometry and differential measurement, adjusting for changing blood volumes. It incorporates photoplethysmography to eliminate light absorption by the skin and bones to measure bilirubin content solely in the blood, allowing for precise measurement across different skin tones. Due to biohazard limitations, dyes with similar absorbance properties were used as substitutes for bilirubin and hemoglobin during the calibration and testing of the device. Testing with 8 phantom solutions covering a wide variety of patient conditions showed the device to be able to consistently measure and display bilirubin and hemoglobin concentrations with a 2.8% error rate. In the future, this device could replace TsB and TcB as a more practical solution for jaundice diagnosis and monitoring.

Integrating Wearable Technology for Improved Epilepsy Management

Mariam Iqbal

Epilepsy is a chronic neurological disease that affects millions of people worldwide . According to the World Health Organization (WHO), around 50 million people have epilepsy globally. It is characterized by recurring seizures in parts of the body or the entire body, and/or a loss of consciousness. Epilepsy is a brain disorder in which groups of nerve cells, or neurons, in the brain start misfiring and sending the wrong signals, which causes seizures. Anyone can be diagnosed with epilepsy, the cause being structural, genetic, infectious, metabolic, or immune. There are many different forms of seizures ranging from focal to generalized. Focal epilepsy is when the seizure originates from a specific part of the brain, while in generalized epilepsy, the abnormal electrical activity can originate from both hemispheres of the brain. It is estimated that 1 in 10 people will have a seizure in their lifetime. Seizures can vary from a few seconds to a couple of minutes and can range from simple frozen stares to full blown body convulsions. Some seizures can make a person fall and hurt themselves. Seizures that are more than five minutes long are a medical emergency and require emergency medication.

Leading to and during a seizure, a person can experience low blood oxygen levels with sometimes Oxygen saturation 90% in 20% -30% of the cases. Seizures can also change the pulse and cause an increased or decreased heart rate. Since seizures do not come with any warning and epilepsy is very different from person to person , it becomes very important to be able to collect data to provide individualized monitoring & appropriate treatment options for paramedics and doctors. Having this data can help predict a pattern to determine when a potential incident may happen, helping the patient effectively control seizures.

My project will create a device that detects seizures through sudden changes in motion and measures oxygen and pulse rates at the time of the seizure. The device will be a wearable which constantly monitors this data and stores it in a cloud database. The device will also alert loved ones by text and phone call in the case of a seizure and a fall.

In order to design my wearable solution, I used the ESP32 IoT (Internet of Things) chip which can communicate with various sensor chips and a cloud database to log all the data collected. I utilized the MPU-6050 3-axis accelerometer gyroscope sensor for detecting abrupt motion and falls, and the MAX30102 Low power heart rate sensor, Pulse oximeter to measure oxygen levels and pulse rates at the time of the fall. The ESP32 chip reads the data continuously from the sensor chips and logs the data using IFTTT.com and Google sheets. Data collected is used to understand the pattern and frequency of falls, which are considered seizures, for assessments of timing, pulse and heart rate during the incident for the healthcare provider to calibrate the treatment plans to the specific patient. In addition, the ESP32 will trigger a text message alert to loved ones in the event of a fall. Clicksend text message service is used for sending text alerts.

In conclusion, the device worked as per the design to detect the fall, log data on a cloud database, and alert loved ones via text upon detecting a fall/seizure.

Orthotic Hand Brace to Improve Range of Motion in Patients with Cerebral Palsy

Sophia Caramanica

People with spastic cerebral palsy sometimes develop contractures in the hands that cause the hand to close in on itself, reducing the range of motion (ROM). For children who use their hands to learn about the world, this is a problem. Current treatments include orthotics, which tend to be bulky and uncomfortable, and electrical stimulation which has proven effective in alleviating pain and reducing spasticity. The objective of this device is to reduce the pain caused by contractures using electrical stimulation and stretch out with contractures with the orthotic. To test the device, the angles of each participant's fingers were measured without the device. Then, the angles of the fingers were measured with the orthotic on. The control group was measured without electrical stimulation, and the test group was measured with. Finally, the participants gave feedback for how the orthotic could be improved. The average change in finger angles was 1.88°. The control group had a 0.67° average change in angles higher compared to the test group. These results indicate that the proposed orthotic does increase ROM, and feedback from participants determined that the TENS unit did relax the muscles, however the TENS did not help improve ROM. Future testing will be done over a longer period to see the device's effectiveness over time. Children who have cerebral palsy deal with chronic pain and are limited by their reduced ROM, but this device can increase their ROM and overall quality of life.

Keywords: cerebral palsy, contractures, range of motion, orthotic, electrical stimulation

Intelligent Two-Webcam Microscope for Studying the Cognitive Abilities of Social Multicellular Animals and Biorobots Synthesized from Cells.

Danylo Kozyrytskyi

The key to understanding the functioning of the brain as a whole in metazoans, which are at a higher stage of evolutionary development, is to obtain patterns of nerve cells in the simplest ones.

My earlier discovery of RGB phototaxis in the marine model animal Trichoplax (Placozoa) allowed me to formulate a hypothesis about the presence of a protobrain. To test this hypothesis, a specialized microscope is needed.

I have developed a two-chamber microscope with a hermetically sealed outer casing that allows for the automation of long-term studies under simulated living conditions, depending on the level of illumination, spectrum, and pressure level (up to 3 atmospheres). To simulate the depth of habitat, I placed a two-webcam microscope in a steel case and modified the stage design, which improved the image quality from the second camera. To automate the movements of the webcams, I decided to use a delta robot system with servo motors. Video information about the behavioral reactions of an individual animal in microscope mode and the entire flock in macro mode with video recording is displayed on the computer screen. The structural components of the microscope were designed in Fussion 360 and 3D printed on a Tevo Tarantula 3D printer using PLA plastic.

The goal of my project is to develop an intelligent two-webcam microscope to study the cognitive abilities of social multicellular microanimals and biorobots such as Xenobots and Anthrobots.

The use of such a microscope in research will expand our understanding of the functioning of the primary patterns of brain structure.

Machine Learning Approaches to Enhance Inverse Kinematics in Robotics

Christopher Yoo

Purpose
Robot-assisted motor rehabilitation is beginning to emerge as an effective treatment option for patients. Accurate movement control remains an important issue in robotics. To create the desired end-effector movement, a technique - called Inverse Kinematics, is used to calculate each joint angle. This study aimed to test the hypothesis whether Machine Learning algorithms can be used to predict the end-effector position of a robot arm.

Procedure
Synthetic data representing various positions of the end-effector was generated by randomly sampling the joint angles within their operational ranges (n=8,000). Forward kinematics was used to calculate the corresponding positions. Part (80%) of these synthetic data was used to train three machine learning algorithms- (1) Linear Regression, (2) Random Forest Regressor, and (3) Deep Neural Network (DNN). The performance was measured using the percentage of mean squared error (MSE) in reaching the target, with respect to randomized positioning. The algorithm was applied to control the triangular trajectory of a 2-joint robot to simulate exoskeletal motion.

Results
Performance was similar across the models, with slight superiority seen from the Random Forest Regressor. Divisional scale factors in joint angle were introduced within the Random Forest Regressor model to limit the effector movement range , which showed improved performance, with applicability to the robot arm.

Conclusions
The Random Forest Regressor outperformed the more sophisticated DNN although the increase of training data and optimization of training parameters may alter the outcomes. This research showed the potential of integrating machine learning techniques with robotics to enhance operational efficiency.

Keywords: Robotics; Machine learning; Inverse kinematics; Python programming

Bionic Insect Jumping Device

Yuyao Wu

A bionic robot has great potential for practical applications. The robot could be expected to enter structurally damaged areas to rescue, deliver medical resources after a disaster, and carry out pipeline inspections. It has many possibilities for extension as well, including space and underwater exploration. This study demonstrates a robot that can jump on a relatively rough surface, and towards 6 times its height and 4 times its length. Structurally, a 4-link structure for the legs was utilized. The force accumulation was achieved by the spring and the meshing of the big gear and the missing teeth of the pinion gear, causing the spring to be elongated and force to be accumulated. As the missing-teeth gear was disengaged from the large gear, the instantaneous release was achieved. In subsequent iterations, the stiffer spring and extended the time of force storage by using gear sets were employed to build up the elastic potential energy of the spring, which contributed to the great progress in the robot's jumping height and distance. Finally, five robots were made. During the process, the robot can jump on relatively rough surfaces, control the ejection angle via servos, and jump continuously. Also, six types of materials were explored, and eventually the main parts of the robot are made of aluminum alloy or carbon fiber; gears, and other parts of the transmission are made of stainless steel and brass. It is hoped that this study could contribute some help for other scholars exploring jumping robots in the future.

Keywords: Jumping Robot, Rescue after disaster, 4-link structure, Force accumulation, Missing teeth, Gear Transmission

A Model for Smarter Urban Intersections

Ludovica Melodia

There are millions of traffic lights throughout the world that are always on, constantly consuming energy. The energy that is used from all of these traffic lights impacts the environment. Energy waste is a prominent issue in today's world, which is why it should be an important societal goal to work towards energy efficiency.

Internet of Things (IoT) is a concept with which objects in our environment can communicate with each other to create more efficient systems. Last year, I created an IoT model for a traffic light which only turned on when it could sense a car in range. Unlike other already existing sensor operated traffic lights, the light in my model communicated with cars using Bluetooth, enabling it to have an accurate sense of where each nearby vehicle was. This year, I expanded on this model to add a pedestrian component. I used two Arduino circuit boards with WiFi capabilities. One board, representing a car or person, has a GPS attachment, and sends its speed to the second board, representing the traffic light. If the speed received is that of a pedestrian, the light cycle starts green for the pedestrian and red for the vehicle, and then changes to allow the vehicle to pass after a set number of seconds. If the speed received is that of a vehicle, the lights cycle through in the opposite order.

I tested the model in 20 trials, 10 for the vehicle component and 10 for the pedestrian component. In these trials, I recorded whether or not the correct lights turned on based on the speed of the GPS. In all of my trials, the model worked without error. My hope for the future is that this model can be implemented in real traffic situations to make urban environments more efficient.

The Optimal Analog Calculator

Alexander Bove

This experiment centered on the construction of an analog calculator. Though the purpose was initially determining a means via swapping components to expand the range of possible input values and the accuracy of results, difficulties in calibration prevented this. Hence, the initial hypothesis that swapping components with higher-precision ones would improve accuracy and broaden the range of possible input values for which output would be usable was replaced with a goal of creating a usable analog calculator and determining any means to improve it. A fundamental design principle of the experiment was to use DACs with thumbwheel switches for the precision of inputs to make the experiment repeatable, though all calculations were analog.

The procedure, following the construction of the op-amp-based adder and multiplier, was to perform addition, subtraction, and multiplication. Addition was done by entering values into the input switches and recording the result on the voltmeter. Subtraction used the adder with inverted DAC reference voltages. Multiplication required reverting the reference voltages and connecting the DACs to the multiplier, and adjusting the multiplication reference voltage switch until results were accurate. Meter outputs were recorded and compared to known correct results.

The new hypothesis was that results would be inaccurate towards the upper limit of the op-amps' range and towards 0V, as small differences in results are a large percent error at small scales, and the op-amp introduces error at the high end due to limited range. The control was always 1.00 for both inputs. The hypothesis was supported, for 6.00+5.00 yielded 0.09% error while 0.04+0.08 was low by 16.67% despite both falling shy of the correct result by less than 0.03V. Conversely, 8.00+5.00 was 6.62% inaccurate because the proper result would exceed the voltage cap. Notably, multiplication was less accurate than addition and subtraction were, and subtraction was less accurate than addition, with the lowest error for multiplication being 4.09%.

How Does Temperature Affect Battery Life?

Liam Sheehan

The purpose of this experiment was to understand how cold temperatures affect the voltage of alkaline batteries so batteries can be used in ideal temperatures to preserve their lifespan. The experiment tested the hypothesis that if alkaline batteries are exposed to cold temperatures, then their voltage will significantly decrease, because the electrolyte freezes. For this experiment, five sets of three flashlights containing batteries were placed at five different temperatures , and the voltage of each battery was recorded at eight hour intervals for 120 hours. To ensure the results were consistent among different battery brands, one flashlight in each set contained Energizer, Duracell, and Rayovac batteries respectively. Each set of flashlights were placed in different temperature controlled environments which varied from -40° to 70° Fahrenheit. The expected outcome was cold conditions would weaken the batteries ability to sustain voltage when compared to warmer temperatures. However, the experiment proved that the voltage of the batteries over time increased up to a certain temperature and then started decreasing rapidly once it was too cold.

Modular OLED Infrared Digital Night Vision Goggles for Critical Search and Detection in Underdeveloped Countries

Feichen Li

Kyle Wu

Lucas DeFilippo

Our project was the design, engineering, and building of digital night vision goggles in order for people without the access to lights to see at night, and potentially to help search and rescue teams look for missing people in the dark. We investigated how we could replicate and more cheaply build the night vision goggles, all while retaining the quality, and in some cases improve them. We improved the input lag for the screens compared to the original , and also added a water resistant element to it. Our display utilizes an OLED, which is better quality than an LCD. We started by identifying the key pieces necessary, and modified them to benefit our uses. We then decided to put small displays in the lenses of our night vision goggles, in order to allow the display delay to be less than the original. Afterwards, we designed a wiring system that would allow all the wiring to be fit into the small compartment in the middle. Finally we tested it out and discovered that it did indeed allow us to see in the dark, and would definitely allow people in third world countries and search and rescue teams to be able to use it.

Designing a Novel Aircraft Powered by an Innovative Electromagnetic-Accelerated Ionic Propulsion System

Ibrahim Afzal

Tayyab Afzal

Thomas Le

Our project focuses on sustainable aviation by exploring the feasibility of solid state aircraft powered solely by electricity using an ionic thruster. Through meticulous experimentation and innovative engineering, we have demonstrated the viability of this groundbreaking concept. While our experimentation showed limitations in accelerating ionic wind using magnetic forces, however our success in designing a lightweight design and energy/thrust optimization marks a significant milestone in aeronautical engineering. Our findings hold the potential for a future of environmentally friendly and efficient air travel . Our goal is to reduce CO2 emissions and lessen climate change's impact. Future research could focus on refining ionic thruster designs and magnetic acceleration systems to enhance aircraft performance. Additionally, exploring better materials to further increase energy optimization and overall power. This will be crucial for creating airplanes that are more environmentally sustainable. We envision a future where air travel no longer negatively contributes to environmental health , and instead is a more cost and energy efficient means of travel .

Bio-physical Sensing of Feeding Pattern on Invertebrates and Application for Smart Recreational Fishing

Haruki Ohara

Recreational fishing is a beloved pastime for people of all ages, with over 200 million anglers worldwide generating substantial economic benefits. Squid fishing setups are slightly different from traditional fishing types, typically consisting of a special jig (called Egi) to entice squid. The goal is to trick the highly intelligent creatures into grabbing the jig, mistaking it for their prey. While detecting such squid bites and knowing when to time the hook is critical, this can be quite difficult as their biting force can be too subtle for many anglers. To help such struggling anglers, a more insightful and effortless method was devised.

One of the challenges in squid fishing, similar to other recreational fishing, is that an angler makes the jig dance underwater to entice the squid–something that generates false signals in the sensor output like a fishing line tension sensor. In a previous paper submitted at MSEF, such hand-motion-related noise was successfully canceled from the line tension signal by creating a simple dynamic model of the fishing rod with the employment of additional hand-motion sensors like an acceleration sensor.

In this research, a new prototype was designed with improvements in areas such as electronics, mechanical design, dynamic modeling, characterizing, and post-signal processing with the addition of the gyro sensor. Matlab and Simulink were then used to analyze the raw data captured during the fishing trip. The model and signal processing scheme were then applied in two exemplary cases of raw data that contained squid bites and activity. The results show short pulses preceding the time frame where the squid was actually hooked, which indicates some sort of squid contact with the lure. This may mean that squid was actually testing the lure at that time, which anglers can sometimes feel; however, further research is needed to confirm their presence.

SpinTOL: Research and Development of a Highly Efficient UAV

Yuze Cai

This is my second year working on SpinTOL, a platform that was originally inspired by past works in the Singapore University of Technology and Design's Airlab such as [1] or [2], and later on by Nicholas Rehm's project on Youtube [3]. The intent is to create a novel drone capable of verticle take-off and landing while maintaining the ability to perform fixed-wing flight.

Traditionally, VTOL aircraft have always had to compromise on either hover efficiency or forward flight efficiency. This trade-off was largely due to technological constraints. Helicopters, while efficient in hover with their large blades, lacked forward flight efficiency. At the same time, fixed-wing VTOL aircraft, efficient in forward flight, usually achieve vertical flight with small, inefficient quadcopter motors. With SpinTOL, I combined the efficiency of helicopters and fixed-wing aircraft by creating a fixed-wing aircraft that can spin its wings like a helicopter for hover and still retain the ability to fly forward. SpinTOL achieves this hybrid model by having quadcopter motors on its two wings which can be used to propel it in forward flight but spin it around when the two wings tilt in opposite directions with the help of a tilting servo mechanism. SpinTOL has three phases of flight: forward flight cruise mode, which will be denoted as C mode, spinning hover mode, denoted H mode, and transition mode where SpinTOL hovers with its wing motors only. I spent the first year of my research independently testing each mode on different test prototypes. This year, I combined all modes into one prototype, focusing on creating the most efficient hover/forward flight capable drone. Aiming for ultra-long hover durations of up to 1.5 hrs and a forward flight operating radius of 30 kilometers, I faced challenges in developing a sound control algorithm for the drone, designing custom software and hardware, and testing the drone in rigorous simulated and real-life environments.

The applications of SpinTOL are immense. With the improved range and hovering duration compared to traditional multi-rotors, SpinTOL can be used for search and rescue missions, disaster relief, anti-poaching, signal relay, aerial mapping, and much more. Throughout my design process, I've made sure that each step and calculation is repeatable and scalable so that different versions of the drone can be designed with ease.

The current prototype of SpinTOL comes in at 1.3 kilograms or 2.9 pounds, leaving little room for failure. Thus, I have only attempted forward flight mode and non-spinning hover as additional testing is required to deem it safe to perform spinning. I have completed these additional tests in both smaller prototypes and the simulations I created, and I expect to be able to perform spinning flight testing before the end of March 2024.

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A Tensegrity-Based Inchworm-Like Robot for Crawling in Pipes of Varying Diameters and Angles

Yuxian Liu

Under rapid urbanization of areas, cities have grown consistently in size as well as their underground piping systems. Yet, the degradation of the pipes within such systems has become a growing problem, which can lead to serious accidents. Examples include natural gas pipelines, which often extend on for long distances to reach different cities and even countries to supply them with fuel. Upon extended periods of usage, these pipes are subject to degradation both on the inside and outside, and without proper maintenance examinations, they are at a high risk of bursting and causing harm to the people as well as the environment. To thoroughly check such piping systems requires views of both external and internal conditions of the pipes. External methods of checking are common, but developing internal methods of checking are difficult due to the limited space inside the pipes. Thus, many pipe-crawling robots were invented to solve this issue. Minimizing the number of electronics and wires in such robots, lower its control complexity, and ensure a stable structure has become urgent problems to address. Additionally, due to the varying diameters of the pipes, developing a module independent of a closed-loop control system that is also structurally stable and adaptable to its environment is another problem that awaits to be solved.

This paper proposes a tensegrity-based robot of indeterminate structure used for crawling inside tubes of various angles and sizes. The proposed robot is relatively simple in design, allowing it to be manufactured and assembled quickly with a relatively low cost; the robot has a larger operation range with a battery attached to its body and commanded by a controller; in addition, the proposed robot is capable of crawling in vertical pipes as well as bent ones, and can also adapt to pipes of various diameters.

Optimized Autonomous Caregiving Robot with Facial and Speech Recognition

Eric Nie

In this project, I aimed to design a solution to address the shortage of caregivers. A lack of staffing, coupled with the great need, from the elderly to the youth, who struggle with human machine interaction by hand has created a serious problem in today's society. As such, I developed an optimized autonomous caregiving robot with machine learning, facial and speech recognition, Internet of Things (IoT), database and local networks.

In order to create a supporting structure, custom parts were designed using Computer-Aided Design (CAD) software to be then laser cut from environment-friendly plywood or 3D-printed for components of complex geometry. A Raspberry Pi 4 Model B single-board computer is used for the robot to perform tasks such as facial recognition, speech recognition, internet communications, and audio output. With the use of a machine learning algorithm, OpenCV, the robot can be easily trained to recognize certain faces. Then, if an unrecognized face is detected, the robot will give a warning and send an alert email. Meanwhile, if a recognized face is detected, the robot will begin to take input or commands using speech recognition, which relies on the recognition of patterns and keywords within words. When certain commands are initiated, the robot may be required to perform physical actions, such as providing medication or treatment, which the Raspberry Pi communicates with an LEGO MINDSTORMS EV3 brick to perform the aforementioned tasks.

In addition, it is desired that all important human-machine interactions, whether it be speech or facial, can be logged to retain information. As such, a locally-connected SQL database is used to log all events and interactions. In addition to being stored locally, which maintains data security and privacy concerns, the SQL database is used by the caregiving robot to help each member in the family per their linked information, greatly enhancing the caregiving robot's capabilities both functionally and socially.

In addition, the EV3 brick also controls the automatic movement of the robot in the form of a PID controlled line follower. From tests that were conducted, the optimal motor speed was found to be 35 rpm, as such value allows the robot to both effectively read and process the line, while maintaining a satisfactory time. Also, it has been observed that the parameters of the PID controller directly impacts the stability and the efficiency of the caregiving robot, with optimal values for the proportional (kp), integral (ki) and derivative (kd) gains being found to be kp = 4.0, ki = 0.07 and kd = 4.0.

In sum, using my interests and skills in artificial intelligence, the IoT, robotics, and other novel technologies, I was able to successfully construct a solution to the real-world problem of shortages of caregivers.

Novel Solution for Generating Energy for Electric Cars

Jordyn Meehan

Across the United States, electric cars are being used. However, for an average Tesla, the car can only travel between three hundred and four hundred miles before needing to be charged. This can cause the driver to be inconvenienced and annoyed. In order to overcome this issue, I decided to create a self sustaining generator that is able to charge the battery pack of the car. This means that the electric toy car will not need to rely on any other energy source. This model was a success, and an LED voltage meter was added to the body of the car to make the results easy to read. In the future, this model could be applied to modern day cars to make them self-sustaining so that there is an endless supply of power and no need to spend countless hours charging one's vehicle.

Crosswalk Safety: Using Motion Sensors to Decrease Accidents

Tyrone Manifold

Despite advancements in using crosswalk mechanisms for pedestrian safety, crosswalk accidents remain a current concern, with thousands of fatalities reported annually. This project investigates the potential of using motion-activated light sensors to improve crosswalk safety in low-visibility and distracted drivers conditions. Based on the desire to reduce pedestrian accidents and the current types of mechanisms available for pedestrian crossings, the development of motion sensors and the current challenges in pedestrian-vehicle accidents, I hypothesized that installing motion-activated light sensors at crosswalks would increase visibility for drivers, thereby reducing accidents.

We utilized Raspberry Pi 5 technology and various sensors to create a prototype system that illuminates upon detecting pedestrian movement. The experiment was conducted in a controlled environment, imitating a crosswalk scenario during low-visibility conditions. Our results showed a notable improvement in the detection of pedestrians, suggesting that such technology could significantly enhance crosswalk safety. The experiment is to demonstrate the importance of innovative technological solutions in addressing pedestrian safety and to offer other options for further research in real -world applications.

A Launchable Aerial and Underwater Rotorcraft Robot

Lixian Zhou

Coral reef bleaching is a significant indicator of the deterioration of coral and marine ecosystems. If detected in time, people can protect the area to prevent further bleaching. Since devices or methods for large-scale detection are still scarce, this research designed a new type of rotorcraft that is launchable and can drift with water, providing a platform for both bleached reef locating and other marine research. The rotorcraft is designed to be a foldable cylindrical quadcopter. Four rotors ensure its stability and portability; the cylindrical shape ensures its verticality, which enables it to take off from the water; the foldability of its arms reduces air-drag when launching and protects the rotorcraft from possible damage caused by impact. The mechanical structure can be divided into three parts. The top storage chamber, the heaviest among the parts, contains electronic components. The mode switching chamber contains a series of mechanical structures that enables arms to unfold when the actuator extends. The bottom support chamber contains the actuator, the optic flow sensor, and the base. The electronic system includes power, control, and mode-switching systems, along with communication protocols and sensors for data collection. Calibration processes have been carried out on the INAV platform to ensure the flight stability. Waterproof measures have been implemented to protect the rotorcraft during underwater operations. After experiments, it functioned normally and stably in terms of flight, waterproofing and camera capture. Possible future work is also introduced, considering the battery's capacity and PLA frame's mechanical durability in water.

Designing a Prototype of an After-market Motorized Window Opener

Brandon Guyott

Justin Romanelli

The basis of this project revolves around the idea of operating a window with a remote control. The initial design was created after seeing people, especially the elderly and those with muscle-based disabilities, struggle to open windows without the help of others. The purpose of this project is to allow these people the ability to open a window without needing said help.

Achieving that goal was done through programming a Raspberry Pi to receive commands from an IR remote, which in turn commands a linear actuator to extend or retract, thus opening or closing the window. The linear actuator was connected to the top of the window sash, so the system would pull the window up or push it down during operation. A safety system was also designed, involving the operation of a distance sensor to detect objects in the window, and if an object is detected, immediately cut power to the piston. 12 trials were set up (3 trials per each speed level), each trial containing a measurement of operational noise, time to open the window, 5 consistency tests (open and close on one button press), and 3 safety consistency tests.

The time at Speed 4 was fast enough to meet the criteria, but the time at the slowest speed was significantly slower than the goal (+20s on average). The noise on Speed 4 was slightly over the limit set by the goals, though by a slim margin (+0.1 dB on average). The consistency showed that the system was successfully working on a single button press frequently enough to meet its goals, with an average success rate of ~98%. The safety consistency remained at a solid 100% throughout the experiment, as the 3 objects were always detected (brick, highlighter, & stuffed animal).

The data collected suggests possible improvements to the system. The speed level system could be reconfigured to resolve the issues surrounding exceeding time and noise. Implementing a microphone and opening the window using voice commands is a promising and feasible idea. The system shows promise in its applications, as it would work for those who have muscular issues, either from age or from a disability.

Higher Efficiency Dynamic Rocket Engine Nozzle

Timucin Erbas

Modern day rocket engines employ nozzles to transform on-board fuel-derived, high temperature and pressure gasses into a high-velocity exhaust that propels the rocket forward. The efficiency of a rocket engine largely hinges on the velocity and directional precision with which the engine's nozzle ejects propellant gasses. However, due to the static nature of traditional nozzles which are optimized for only one altitude, rocket engines spend most of their flight expelling gas in slightly skewed angles causing inefficiency.

In this project, a dynamic rocket engine nozzle which is able to adapt its shape to optimize for every altitude the rocket experiences was developed. The project has two main components: a nozzle adjusting mechanism capable of physically facilitating these shape changes, and a contour generation software that instructs the nozzle adjusting mechanism on how exactly to adapt its shape to optimize for every altitude. These two systems work together over the rocket's flight to achieve optimal exhaust directionality in any given altitude, achieving greater efficiencies.

The dynamic rocket engine nozzle was tested through a series of simulations conducted on ANSYS CFD, in which the thrust of the rocket engine was measured in environments resembling many altitudes up to 66 kilometers above sea level. It was found that compared to a traditional static rocket engine nozzle, the dynamic rocket engine nozzle achieved a ~1.92% higher efficiency, which would decrease the payload costs (cost per kilogram to space) by ~41%.

Magnetic Orthosis

Haaris Khan

Samuel LeDoux

Neurological and physical disabilities have impaired the manual function of many people worldwide, especially in developing countries. The purpose of this project was to construct an orthosis, designed to facilitate the movement of the hand and mitigate impairment, using cost-effective and minimal systems for simple assistance. The scientific concept that inspired the orthosis is magnetomicrometry (MM), where an array of magnetic beads is implanted in muscles and the contractions are detected through sensors, sending the exact movement to the motors. Through magnetomicrometry, the orthosis calculates the hand's position depending on the magnetic array's deformation and adjusts it accordingly with latex resistance bands. In order to create the physical model, CADwasused to design the prototype and 3-D print the attachment to the hand/palm. The model has built-in rails where the magnet beads would be inserted and then attached to the bands, so that when the beads traveled on the rail, the bands would be strained and create movements of the fingers. To accurately depict the movements, an animation was created on Blender where the orthosis was placed on a 3-D model of an arm.

Smart Care Shoes

Jayce Chen

This project created a special pair of shoes with built-in technology to help improve foot health and the prevention of falls for the elderly in the world. The shoes included sensors to detect obstacles and features to make the foot more supported. The development process included design sketches, 3D modeling, material selection, electronic programming, and rigorous testing. After designing and testing these shoes, the results showed they could help seniors by making walking safer and more comfortable in daily life.

I See The Light

Benjamin Phillips

Solar Panels lose about 15%-20% because of the installed angle. This means we are losing potential energy. If I modify a solar panel with servos and light energy, it can gather more potential energy compared to a stationary model because it will be perfectly angled.

Can Ultrasound be Used as a Solution for Vision Impairment?

Soumalya Chatterjee

As we all know, people with visual impairments rely on canes or service dogs to navigate their paths. These can be challenging since service dogs can be difficult to train and canes cause people to have their hands occupied . The solution to vision impairment as of right now is LASIK surgery. Unfortunately, some individuals may not have the necessary money to receive the procedure. However, I researched that bats and dolphins can identify almost anything in pitch black darkness via echolocation. Echolocation is a physiological process that uses high frequency sound waves that bounces off objects (such as prey or trees) and is reflected to the emitter by said object. I hoped to create a device that uses an ultrasound sensor and a buzzer to indicate how far a subject is from an obstacle, so that people with vision impairments have a more reliable and independent way of navigating their surroundings. One side of the sensor will transmit a sonic pulse to a certain distance — which cannot be heard by the human ear— that will reflect off an object and return to the other side of the sensor , the ultrasound receiver. After building the prototype, I tested it by gluing/taping it on a glove. Then, the experiment I conducted was having my adult supervisor make five obstacle courses of varying difficulty level (changes in height, and quantity) out of Jenga Blocks. I was not able to see what the course looked like, for I was wearing a blind fold to mimic a real-life experience. I had to navigate through the obstacles as fast as I could, relying only on the machine. The time it took for me to get out was proof that the machine was effective.

Design of a Multi-legged Robot with Extraterrestrial Terrain Exploration and Sample Retrieval Functions

Yanchen Lu

Exploration of formerly uncharted terrain has sparked demand for robotic systems capable of locomotion across rough geometries of terrain. To construct such robots, researchers and engineers have drawn inspiration from biotic organisms. Multi-legged robots, mimicking the movement of multi-legged insects, could significantly advance robotic capabilities on uneven terrain. In industrial or urban settings, multi-legged robots play indispensable roles in negotiating treacherous settings, such as toxic nuclear plants and aftermaths of natural disasters. In environmental and agricultural settings, these robots can forecast parameters such as soil quality and mineral composition, and document collateral damage from storms. In rough geometries of other planets, these robots could ensure the reliable transport of tools, samples, or other data.

The prototype proposed in this paper challenges contemporary designs in three primary ways . First, its elliptical gait scheme—which mimics the undulating movement of centipedes—differs from other multi -legged robots. Secondly, this unique mechanism eliminates the need for independent leg control, simplifying the construction process. Finally, the robot will be employed in extraterrestrial settings, a domain where multi-legged robots have yet to witness development.

This paper will conclude with a series of experiments that verify the effectiveness of this prototype .

Keywords: Multi-legged robot, extraterrestrial applications, elliptical gait scheme

Minimizing Fuel-Oxidizer Mixture Inhomogeneities in Rotating Detonation Engines

Kayla Vallecillo

The rotating detonation engine (RDE) is widely considered as one of the most promising and interesting areas of propulsion research due to its high levels of energy output and thermal efficiency. The current use of separated fuel and oxidizer injectors, which aid in detonation wave combustion and propagation, prevent the interference of high detonation wave pressures with material injection. However, this injection scheme has produced inhomogeneities in the fuel-oxidizer mixture that decrease the engine's overall propulsive and energy-producing capabilities. A standardized, 2-dimensional computational domain was developed in Ansys Fluent, with the aim of developing a more effective injection strategy. The simulation featured a closed detonation channel and an open injector inlet to interchangeably test existing injection geometries. Several injection schemes, which varied by diameter, distance, and angle of injection, were tested to evaluate the most effective existing injection geometry. These variables were then altered to determine relationships between injector structure and mixture homogeneity levels, applied in developing a novel, more effective injection scheme. It was found that through the adjustment of angle and diameter of the existing axial-triplet scheme, fuel-air mixtures reached homogeneity levels of 99.2%. Using a novel and strategic approach, this model demonstrates the improvement of multiphase, non-reacting fluid flows and high-pressure material injection without the use of high-fidelity models. Through the iterative adjustment of injection-specific variables in the RDE, the level of inhomogeneity within fuel-air mixtures was decreased by pursuing the improved model, and could advance high-pressure, thrust-producing combustion systems for future rocketry and energy applications.

A Novel Water-based Cooling Approach to Increase Solar Panel Efficiency

Nicholas Giza

As the world becomes increasingly more dependent on its power grids, it has simultaneously become more dependent on fossil fuels. To offset this harmful reliance, photovoltaic solar panels (PVs), can be used to cleanly and renewably produce electricity. One major flaw that plagues solar energy is the fact that PVs lose significant amounts of efficiency when hot. In fact, for every 1□ increase in temperature (above 25□), there is a 0.08% to 0.45% drop in power output efficiency (Alktranee & Péter, 2023). With normal operating temperatures as high as 70□ (Akal & Türk, 2022), this is detrimental to electrical output. In response, this study produced a closed-loop, water-cooling system powered by thermoelectric generators (TEGs) to reduce solar panel temperatures and increase performance. Two forms of apparatus were designed and analyzed. Finite element analysis in SolidWorks simulated coolant flow and served as a visual representation for to-scale design. FEM results were tested in a physical environment where one control PV and one water-cooled PV-TEG were set up under a 1728W array of halogen light bulbs. In testing, SolidWorks Flow Simulations suggested relatively equitable coolant flow rates, supported with f-tests. Physical testing suggested a 4.70W or 10.18% average increase in efficiency/power output; enough power, when scaled to a fully powered PV, to support the cooling system. With this in mind, entire solar array cooling systems can be designed that scale this system accordingly. The implications of this highly functional, closed-loop cooling system for PVs provide immense potential for a more sustainable planet.

Keywords: Photovoltaic Cooling, Thermoelectric Generators, PV Efficiency, Flow Simulation, Solar Simulator

The Application of Generative Design in the Optimization of Model Rocket Motor Nozzle Contours for Maximum Specific Impulse

Matthew Lyubchik

Generative design, a process where a computer procedurally generates a component based on various parameters and goals, is primarily limited by insufficiencies in the processing speed of computers. As this boundary is pushed in the present day, generative design has started to find its use. In rocketry, a marginal increase in efficiency can result in a proportionally greater decrease in rocket weight, and therefore cost. This project intended to measure the ability for generative design to design a rocket nozzle with similar or better performance than existing nozzle designs. A program, foamGE, was written in C++ which performs generative design using the OpenFOAM open-source CFD engine. Three nozzles were designed generatively using this program. These three nozzles, as well as a cone and a bell nozzle, were each 3D-printed out of metal using an online service called Xometry. The nozzles were mounted to model rocket motors of the model C6-0 and static-fired to measure their force, which was then converted into impulse and then specific impulse. Generatively designed nozzle 1 performs the best out of all five metal nozzles, though the control outperforms them all. This experiment shows a promising future for generative design, as a generatively designed nozzle outperformed two traditional designs.

Advanced Biosignature Detection Model For Finding Extraterrestrial Life using Capillary Electrophoresis

Garima Chauhan

Currently, there are many difficulties when it comes to the development of technologies to find extraterrestrial life on planetary bodies in our solar system and beyond. Most biosignature detection software often receives “false positive” biosignatures if the exoplanet has a moon/orbiting body with its own atmosphere. This causes a signal that appears to be disequilibrium in one atmosphere when it is the two atmospheres blend together. My project is to simplify further and create a technological model that uses capillary electrophoresis to analyze certain aqueous solutions as a proxy for what may be found on exoplanets, and determine the presence of ions/electrolytes within the solution. This model is much more efficient and can work independently of other biosignature software to generate the most possible outcome for life on another planet. What is different about my project and my procedure is I am using capillary electrophoresis , which is primarily used in DNA analysis technologies. I am entirely repurposing technology from another field and using it to be able to detect the habitability of life on other planets. Currently, CE has never been able to become automated, and as far as to test biosignature detection in terms of planetary bodies (The procedures I found were for making the circuit, detecting amino acids, or any other solution). Also, using capacitively coupled electrode detection (the method in which CE detection operates) is incredibly efficient and cost-effective. Lastly, the specific method I am using is highly optimized for real space missions, It’s a rather simple structure and experimentation process to prevent any difficulty if it were to be in a scenario where there are high-hazard levels or toxic chemicals.

Flag Buddy: Using Nitinol Alloy to Reduce the Threat of Scalding

Anika Kale

Scald burns pose a widespread and severe challenge impacting individuals across age groups, with children being notably vulnerable due to their thinner skin and potential lack of supervision or awareness regarding hot liquid hazards. Disturbingly, statistics reveal that out of every ten individuals admitted to burn centers for scald injuries, six are children. Approximately 90% of all burns, including scald injuries, occur in lower to middle income countries. The prevalent practice of boiling water for consumption or bathing purposes exacerbates the incidence of scald burns in these regions due to frequent handling of hot water. This stark reality underscores the urgent need for cost- effective solutions to combat scald burn hazards and safeguard vulnerable populations.

The main objective of this project is to create an affordable , highly visible, and food-safe product that can be used to warn against dangerously hot water before accidental burns occur. The product will be designed to be easy to use, reusable, and easy to maintain, with the target setting being in lower to middle income countries where boiling water for use is more common and thus the chances of scald burns are higher. The flag raises when the water reaches 140 degrees, which is hot enough to cause a 3rd degree burn in children in just a second. Along with the flag raising, the red floating base turns white at any temperature above 113 degrees fahrenheit which is uncomfortably hot for most people.

Sustainable and Cost-Effective Cactus-Inspired Fog Collecting Kirigami

Huiyi Wen

It is a fundamental human right for all to have safe access to drinking water. However, 46% of global population is plagued by freshwater shortage, leading to not only health concerns but also socioeconomic gaps. Effectively harvesting fog water can offer a significant water supply. Fog meets the World Health Organization's drinking water standards, and harvesting fog is cheaper than building conventional water supply systems. It is highly adoptable in many regions with water inaccessibility, such as Chile and Spain since fog is abundant in coastal dry lands. Recent designs for ideal fog collecting meshes usually face setbacks in balancing the cost-effectiveness and the collecting efficiency. Most of the designs are plastic-based. Massive intake from water directly intercepted from plastic meshes cause microplastic buildup over time, which recent studies have suggested is detrimental to human health. Inspired by the conical structure of cactus spines, this work proposes a model that utilizes Laplace pressure to construct a self-pump collecting system with no external energy. It is fabricated by mixing natural wood fibers and pressing them into a thin film, then coating the surface with beeswax. The highest performing set of parameters is examined under a fog flow of 230 cm•s-1, reaching 4321 mg•cm2•h-1, which is 1.5 and 11 times the rates of our control models, harp-like and plate collectors. In massive fabrication, it is estimated to cost under $1 to produce per m2. This affordable, efficient, and environmentally-sustainable model can increase freshwater accessibility in applicable regions with maximized safety.

Natures Guide to Organ Preservation: How the Study of Hibernating Animals Can Lead to New Techniques of Organ Preservation

Camilla Royal

Organ transplantation has the ability to save lives and has been doing so since July of 1883. There are currently over 103,000 people on the national transplant waiting list. Of these organs, the kidney has the longest waiting list. Although once patients are approved for this treatment there are still many roadblocks they must encounter. These roadblocks include: being able to cool the organ without it deteriorating, preserving the organ long enough to be transported and to have the patient prepared for surgery, and heating the organ backup without risking deterioration. Typically organs are only viable outside of the body for 6 to 30 hours. Doctors are consistently looking for new methods to extend the time period in which an organ can be preserved. If a technology was created to increase the time an organ can be preserved, lives would be saved. The circumstances of Chrysemys picta(painted turtle) brumation were observed in order to find solutions to this problem. During cold weather painted turtles enter a state of brumation in the muddy bottom of a pond or lake. Brumation is reptilian hibernation which includes the organism slowing their metabolism and becoming lethargic. In order to survive brumation C.picta lives off of stored fat and slows its metabolism. Due to its environment, C.picta experiences increased pressure and is surrounded by cold thick mud. During this experiment, techniques of organ preservation inspired by C. picta were compared to traditional organ preservation methods like that of a Lifeport Kidney machine which puts ice next to the organ. During this experiment, E.coli was used to model a kidney. It was placed in 6 different variables 2 of which were controls. During the experiment the growth of E.coli was measured over a period of time. Then a new set of colonies were put under hypothermia for 52(trial 1) and 24 hours(trial 2).Their growth after incubation was then compared to the original plates. The results of this experiment supported methods of using increased air pressure and a thick cold substrate as a more effective way of preserving organs. The results of this experiment can lead to new techniques of organ preservation which can hopefully save lives and contribute to the organ preservation problem.

Bottle Upcycler

Aditya Naravane

Plastic bottles are a massive problem. Starting as early as 1947, plastic bottles were being used to distribute liquids to large numbers of people. These bottles are everywhere. A million plastic bottles are bought around the world each minute of every day and that number is only increasing. Many individuals do not recycle them properly, they wind up building up in landfills and floating in the ocean. Even when they are recycled by well meaning people, they cost a lot of energy to recycle. These bottles take 4-6 lifetimes (100 years) to degrade and even then they are turned into microplastics which continue to destroy the environment. Animals in the ocean eat them or get trapped in them, which is incredibly harmful to them. Essentially, these plastic bottles are not going away anytime soon, and we need to figure out how to deal with them before things get worse.

Recently, 3D printers have been blowing up. The first commercial 3d printer was released in 1988 and they've come a long way since then and have blown up in 1st world countries like the US, where there is a 20.67 billion dollar market for them. One of the essential requirements for 3d printing is filament, the string of plastic or other material that gets heated up, softened, and placed on the bed in layers to print the part. However it is not an efficient process, parts of the filament are wasted, or go unused as they are too small to print a part or are of bad quality. This can generate a lot of plastic waste. According to Filamentive, users can generate 40 to 1300+ grams of plastic waste every week, depending on their printer and use case. Also, in the US, filament is fairly affordable, but in many other countries like Brazil, it can be incredibly expensive to purchase this filament.

Polyethylene Terephthalate(PET) is a strong and versatile material, having many things that contribute to its strength and stiffness that sees it being used around the world in many capacities. Its characteristics come from its molecular structure, which consists of long chains of repeating units, forming a strong and resilient polymer. PET has very good tensile strength. Additionally, PET is resistant to moisture and UV radiation. It being lightweight further adds to its versatility.

I had the idea to create a machine that could turn plastic bottles into filament to try and solve both of these problems. I was inspired by CNC Kitchen on Youtube. He used a 3d printer nozzle to pull strips of plastic through. I created the machine using an Ender 3 3d printer so I could test the viability of this filament in fields that need strong filament.

After some research I decided that the 1 of the most important characteristics of a filament is its strength. For a strength test, I printed out a tensile strength testing piece and put the filament to the test in a failure strength test. I used a scale in pounds and pulled on the piece in as consistent of a manner as I could and noted down the weight at which it broke using a slow-motion camera.

Portable Fans: An Untapped Industry Yearning for Modernization

Vansh Mookim

The goal of this project is to modernize the common portable fan. Portable fans are commonly used around the world to provide efficient and effective cooling. The downside to traditional portable fans currently available on the market is that they are inefficient. With global warming increasingly impacting communities worldwide, it is important to reduce electricity consumption whenever possible. This project aims to reduce energy consumption in portable fans by dynamically controlling the speed of the fan based on the temperature of the room. It was hypothesized that this technique will allow the fan to reduce its energy consumption while still being effective. The Smart Fan prototype consists of an ordinary portable fan that is hooked up to a LEGO EV3 that controls the speed of the fan based on temperature sensor readings. The EV3 controls the fan speed based on the temperature sensor readings. These readings are also logged for later analysis. The fan is plugged into a power meter so that energy consumption data can be collected. After building and programming the prototype, experimentation was carried out to determine how much electricity the prototype would consume.
Data collected from the experiment shows that when the temperature fluctuates, the smart fan consumes less electricity than a regular portable fan.

Filtering Methane from Septic Tanks

Aakarsh Tathachar

Aaron Hong

Andrew Wu

Most homes in developed countries have septic tanks that release biogas created from the digestion of organic waste by methanogenic bacteria into the atmosphere. This biogas is composed primarily of methane which is a combustible gas and we want to show that this methane can be used for electrical generation(10, 11). Moreover, methane generated by septic tanks used for electrical generation will reduce the amount of methane released from fossil fuels by converting it into a less dangerous greenhouse gas, carbon dioxide(7). This reduces the overall amount of methane in the atmosphere helping to slow the rate of global warming. One problem with why electricity generation with methane is not possible yet is because biogas formed as a result of this fermentation produces gasses such as “carbon dioxide and other ubiquitous impurities such as water vapor and hydrogen sulfide” (4). While there are mechanical filters that can purify biogas, these are usually too large and industrial for household use. We want to solve the problem of removing impurities generated by septic tanks so that we can use septic gas for energy production. Our design is to develop a microbial filter filled with Anabaena, Rhodospirillum rubrum, Nitrosomonas, and Nitrobacter to purify biogas. We scaled this project down to 1.4 L of compost-filled in a container. Each species of bacteria was put in separate tubes secured with a cap and airtight cork and the Nitrosomonas and Nitrobacter were held in the same container. The anabaena was used to absorb the carbon dioxide and nitrogen through nitrogen fixation. The r. Rubrum was used to absorb the hydrogen sulfide and hydrogen and although hydrogen is a combustible gas, it isn’t as energy-dense as methane. This bacteria was also used to absorb the carbon monoxide. The combined Nitrosomonas and Nitrobacter were used to filter out the ammonia from the original biogas as well as the ammonia created from the nitrogen fixation of the Anabaena. Gas from the 1.4 L digester was let through using tubes connected through each cork. The 3-part filter did succeed in filtering out all the impurities with an average above 90% reduction, however, the output methane was diluted due to inadequate isolation from environmental gasses. We would like to conduct further tests with upgraded sensors to get more accurate data.

Assessing the Ability of Composite Molecular Sieve and Glass Fiber Material in Adsorbing Volatile Organic Compounds

Haoxuan Liu

Currently, the global atmospheric pollution issue is complex and will continue to exacerbate if not properly treated, transitioning from pollution mostly due to coal combustion to pollution due to PM2.5 and O3. Industrial development has led to large emissions of volatile organic compounds (VOCs) into the atmosphere, which are major precursors for PM2.5 and O3. Thus, controlling the emissions of VOCs will be crucial in reducing PM2.5 and O3. To help alleviate this urgent problem, this study assessed the ability of a composite molecular sieve comprised of type Y molecular sieve and type ZSM-5 molecular sieve of varying ratios to capture mixed VOC pollutants through adsorption. In this study, the mixed VOCs consist of ethyl acetate and m-xylene each at the concentration of 200mg/m3. To best simulate reality, this composite molecular sieve is loaded onto a glass fiber carrier that aids adsorption. It was concluded that, while trying to minimize the cost, the composite molecular sieve can effectively capture the mixture of ethyl acetate and m-xylene, reaching its highest efficiency at 93.9% with a ratio (Y: ZSM5) of 50:50. This study hopes to provide insights into composite molecular sieve formulation and application for the adsorption and removal of mixtures of VOCs.

Affordable IA Two-Part Septic System

Maxwell Mingo

Ryan Shea

Ryan Netto

All three of us live on Cape Cod. For a few decades now, algae blooms and nutrient-rich groundwater has disturbed ecosystems in local Cape Cod waters. We found that nitrogen was the primary pollutant, and we wanted to help find a solution to this issue. When we were researching, we noticed that much of the nitrogen comes from septic systems. Due to Cape Cod's sandy soil, the denitrifying step of the nitrogen cycle cannot effectively ensue. The soil is too porous and the effluent (the nitrogen-rich liquid product of septic systems) seeps into the groundwater too quickly for natural denitrification. This nutrient-rich groundwater then harms ecosystems in ponds, creeks and estuaries. So, we devised a septic system that facilitates the denitrifying step. We continued our research and discovered existing I/A systems and created a modified version using its general idea. However, these systems are very expensive and our design should eliminate costs, making it a cheaper alternative for the Cape's septic issue.

If effluent passes into a two-part denitrifying system (that uses denitrifying bacteria like Micrococcus) instead of a leach field, then the remaining solution will be filtered and nitrogen levels decreased. This then would remove the need for a leach-field, and thus decrease costs because labor is the primary expense when installing septic systems.

Field Deployable Real Time Natural Gas Leak Detection

Caroline Song

Natural gas leaks are a serious problem---not only contributing to global warming, but also wasting energy. Although large leaks can be detected easily, small leaks often go unnoticed for years. Thus, the ability to detect small leakages and report them in real time is critical.

Although greenhouse gas monitoring has been an ongoing research topic and significant progress has been made over the years, I didn't find a current product on the market that can be used for real-time in-field detection. After my research, I decided to focus on NDIR technology. It is very sensitive, but it is also expensive, with a high-power consumption. I wanted to focus on combating these points of weakness.

Open path design could take advantage of less restriction of the length, and it cuts down the cost, power consumption and less components. I also investigate the feasibility of using middle infrared LED to reduce the power consumption. However, the LED I tested didn't have enough power. The open path design works. A prototype was built and tested that it could detect gas burst for 5 to 10 seconds within 1.2 meter. Comparison with low cost metal oxidize semiconductor sensor (MQ-4) was also carried out. My project shows it is less affected by temperature and humidity.

A python program was also developed to report the leak data on website (google map).

Advancing Irrigation Systems: A Novel Self-Regulating Sprinkler Responsive to Plant Signals

Junwon Park

Developing efficient ways to use water is urgent, especially in America, where the second biggest source of water waste is the overwatering of lawns. To minimize such waste, a well-timed sprinkler is not sufficient; a system that can detect plant biosignals and determine the right amount of irrigation for a given plant must be developed. In this experiment, resonance and standing waves of grass were triggered using the speaker, and data was collected. Subsequently, the trend of grass losing its ability to resonate to higher frequencies was discovered; based on this result, the Self-Regulating Sprinkler was designed. A speaker emits sound waves in the 400-450 Hz range that grass resonate to if it is moist. If the grass resonates, then the sprinkler judges it has ample water to sustain life, but if it does not, then a sprinkling system provides water to nearby grass. If this system were to be used in American lawns, it would alleviate water shortage due to water waste in irrigation. Additionally, biosignals of other crops could be researched to develop the Self-Regulating Sprinkler for them.

Efficacy and Application of Used Coffee Grounds as Water Filters for Microplastics

Ayati Biswas

Microplastics make up 80% of plastic pollution in the Earth's waterways [Marine Plastic Pollution]. Large pieces of plastic decompose very slowly, and during the process, leech microplastics into their environment. Their miniscule size makes removal increasingly difficult, as they are not visible to the naked eye. These characteristics are why microplastics are potent in bottled water and seep undetected past wastewater treatment facilities into drinking water [Isenaj]. The consumption of microplastics has been linked to endocrine disruption, cancer, and reproductive deficits, etc. [Marine Plastic Pollution]. Coffee is another mass-produced waste product. Though not majorly impactful on the environment, taking one type of waste to extract another is the goal of this experiment. This experiment tested the effectiveness of used, cleaned coffee grounds as microplastic filters for bottled and tap water. The used coffee grounds were thoroughly cleaned through boiling and a simple filter set up. After the grounds were prepared, a similar filter system was used to filter 2 samples of 100 mL potable tap water and 2 samples of 100 mL bottled water through 5g of the prepared coffee grounds. Controls that the filtered samples were compared against were unfiltered samples of the same tap and bottled water. 0.2 mL of all 6 samples were observed under a microscope at 400x magnification, where the microplastics present in each sample were counted and recorded. The bottled water control sample yielded 407±10 pieces of microplastics, and the tap water control sample yielded 332±10 pieces. The 1st and 2nd bottled water samples yielded 117±10 and 112±10 pieces of microplastics, respectively, post filtration. The 1st and 2nd tap water samples yielded 98±10 and 105±10 pieces of microplastics, respectively, post filtration. The bottled water showed an average 71.85% decrease with a variance of 0.0183%2 between the individual percentage points. The tap water showed an average 69.45% decrease with a variance of 0.0298%2 between the individual percentage points. The significant decrease in both samples in the number of microplastics supports the claim that used coffee grounds are an effective filter for microplastics. In the future, these filters can be commercialized as tap and bottled water filters that remove microplastics before consumption. For disposal, miniaturized electrolysis and electrocatalysis chambers can be utilized to break the captured microplastics down into smaller, non-harmful particles.

Emissions-Aware Energy Storage Decision Based on Deep Reinforcement Learning

Jiachi Wang

The transition towards a sustainable economy necessitates effective policies and management schemes to mitigate carbon emissions. One potential solution is carbon cost, which incentivizes emissions reduction through monetary penalties or rewards. An energy storage system (ESS) is essential to integrate renewable energy into low-carbon energy systems. However, an ESS for profit does not necessarily reduce carbon emissions if it replaces high-cost low-emission oil generation with low-cost high-emission coal generation, which calls for emissions-aware decision schemes for ESS. In this research, we propose a novel approach using deep reinforcement learning (DRL) to maximize the profit of an ESS under both electricity price and carbon emission factor uncertainty. The DRL model is trained and validated on historical energy market and marginal carbon emission factor data in California, simulating real-world scenarios of fluctuating energy prices and marginal carbon emission factors. Through a detailed analysis using Deep Reinforcement Learning, this research verifies the effects of carbon cost and discovers the optimum charging/discharging strategy, which maximizes profit while limiting carbon emissions.

Chameleon Roof: Mechanically Switchable Cool Roof Approach to Maximize Efficiency in Hot and Cold Seasons

Juhi Kundu

Urban centers are several degrees warmer than rural areas due to an abundance of dark surfaces, causing increased cooling costs and heat-related illnesses and mortality. White-painted “cool roofs” help mitigate this “urban heat island effect,” but they can also reduce internal building temperatures in winter, causing a “heating penalty.” To reduce summer temperatures while increasing winter temperatures, this study designed and tested the utility of a “chameleon” roof that mechanically flips between black absorptive and white reflective roofing.

Two flippable roofing materials were tested: A black asphalt shingle painted white on one side, and aluminum tiles painted black and white on either side. These were placed on top of an experimental house with an existing grey shingled roof (the control) and exposed to an infrared heat lamp modeling winter and summer sun angles. Temperatures inside the house and on the roof were compared to control.

In winter, black asphalt proved the most effective by heating the inside 8.7% more than the control. In summer, white metal and white asphalt were most effective in reducing inside temperature increases by 36.9% and 34.5%, respectively. In terms of roof surface temperatures, white asphalt performed the best with a summer temperature increase of 9.1% less than the control.

This study showed that the flippable black and white asphalt shingle was the most effective in the dual goal of increasing winter temperatures and decreasing summer ones. Such a solution could influence more homeowners to make roofing choices that help reduce the urban heat island effect.

Using Inverted Airfoils to Reduce Conical Vortex-Induced Uplift on Residential Buildings

Xinyuan (Yolanda) Zhou

Global windstorms are projected to increase in frequency and intensity by the end of the 21st century. This project focuses on using aerodynamic spoilers to reduce wind damage to residential buildings during tornadoes and hurricanes. Three designs were made: Airfoil Spoiler, Vertical Airfoil, and Venturi Tunnel. Grid convergence analysis was conducted to validate Computational Fluid Dynamics (CFD) mesh accuracy. CFD simulations were conducted with created models using the OpenFOAM solvers simpleFoam (steady state, k-omega SST turbulence model). Fan and wind tunnel experiments were also conducted to validate the simulation results. Simulated results were compared to the performance of models created in past papers under the same flow field conditions. Models were found to increase with suction reduction as model height decreased. All three designs performed better than the W1 control model. Airfoil Spoiler was selected and simulated in further detail, varying the corner shape and height of the device. Currently, the case with the highest performance — rounded corner Airfoil Spoiler at 8mm — reduces suction by up to 40.7% from W1 control and up to 34% from the Cube control case. More investigation on the impact of turbulent incident wind is still necessary to determine the new device's performance in the real-world environment.

Autonomous Algal Bloom Control via AI-Regulated Photodynamic Therapy

Kaizar Rangwala

Pranamya Keshkamat

Harmful algal blooms (HABs) are a significant global environmental issue, impacting marine ecosystems, economies, and human health by depleting oxygen in water bodies and causing biodiversity loss. The economic cost of HABs is estimated at approximately $82 million annually, along with posing health risks through toxin-contaminated water and seafood. Traditional methods for combating HABs often harm non-target organisms and ecosystems. This project offers a solution combining photodynamic therapy (PDT) with artificial intelligence (AI). PDT, a cancer treatment used to selectively target tumor cells, is adapted here to precisely neutralize harmful algae without collateral damage to non-algal cells. To ensure that the delivery of PDT against a HAB is not excessive or insufficient, AI locates and assesses the magnitude of blooms using a visual feed from a camera, with an integrated algorithm using this assessment to dynamically adjust PDT treatment to match the bloom's size. To ensure adequate performance, a prototype was considered successful if the AI model had a 90% accuracy in algal bloom detection from the camera feed and if its estimate of the size of the bloom and appropriate intensity of PDT for that size were within 10% of the actual necessary amount (loss). To measure the quantity of algae alive before and after PDT (hence measuring the treatment's effectiveness), spectrophotometry was employed, with an 85% reduction in absorbance after treatment considered successful. The final prototype was 97.49% accurate, with a loss of 0.051%, and an 85.07% decrease in absorbance.

Designing and Testing a Gamified App to Increase the Volume and Accuracy of Household Recycling

Lindsey Paradise

Despite recycling being one of the simplest and most impactful ways for citizens to protect the environment, less than 1/3 of American households recycle. This lack of involvement leads to valuable resources being landfilled and harmful greenhouse gases being produced. To motivate individuals to recycle, an app with the gamification features of a monetary incentive, carbon counter, and statistics page was built using the Flutter framework. The app was tested for one week by three groups of individuals: non-recycling senior citizens, local, and remote. Each participant's recycling output and motivation to overcome recycling barriers, such as not knowing the impact of ones' recycling on the environment, before and after the implementation of the app, were compared. After using the app, over 90% of participants reported an increase in motivation to recycle. Additionally, 100% of participants reported that using the app increased their awareness of the impact of their recycling on the environment. These findings show that gamifying recycling in an app is a viable strategy to increase individuals' motivation to recycle and overcome their barriers to recycling. Additionally, this study has found that non-recycling senior citizens can be motivated to recycle when using a gamified app. This conclusion is crucial because improving recycling habits in a population that does not recycle can make more of an environmental impact than improving the habits of those who already recycle. In future iterations of the app, additional gamification strategies such as points, leaderboards, and teams may be implemented.
Keywords: household recycling, gamification, motivation, app development

Simulating and Developing A Solar Tracking Solar Cell Attachment For Residential Areas

Vasudevan Lakshmanan

From the increase in hurricanes to floods, climate change persists to be a significant problem faced by the international community. Indeed, scientists are determined to bolster the transition from non-renewable energy to renewable energy in an economic, environmentally-friendly manner. Given this urgent demand, further research is vital in one particular field: solar tracking. Optimization of solar trackers (modules that follow the sunlight to optimize energy absorption) is vital in assisting with this transition. There are three types of solar cells: fixed, single-axis, and dual-axis. Utilizing software, such as MATLAB, Simulink, and Arduino-UNO, theoretical data was collected to further grasp the increase in Power Conservation Efficiency (PCE) of dual-axis solar trackers. Theoretical data supports deductions in two timeframes: annually and daily. Firstly, it will project the yearly increase in solar energy absorbed, which is roughly 16%, to conceptualize the economic benefit. Secondly, it will display the times of day when the deviation in energy performance is the highest between models, which is from 10 AM to 2 PM. Alongside this, experimental data was collected to understand the impact of a physical module. Combining both analyses, varying data was collected to understand the impact of residential solar trackers, suggesting a return on investment occurring roughly 16% faster and saving hundreds of dollars annually. Solar trackers integration within the residential sphere, promotes an increased opportunity in the market, especially to benefit the global economy and environment. With the integration of residential dual-axis solar trackers, our planet's economic and environmental impact will be improved, drastically benefiting the entire world.

Solar Powered UV-C LED Water Sterilizer

Megan Ashun

Approximately 1 million people die annually due to drinking contaminated water, making water sanitation a pressing global issue (CDC, 2020). Water may become contaminated with harmful pathogens, such as Escherichia coli, when the sewage infrastructure in a community is inadequate. The Solar Powered UV-C LED Water Sterilizer is a viable option for water sterilization in communities lacking water services due to its high efficacy in reducing the number of coliforms in water, and potential to be a cost-effective option for water sanitation purposes.

For experimentation, water was collected from a Insititute Pond at the Worcester Polytechnic Institute because of the naturally occurring microorganisms in open bodies of water. Once collected, the pond water was treated by the Solar Powered UV-C LED Water Sterilizer at three different flow rates. Afterward, the treated and untreated pond water was tested for coliforms and Escherichia coli using the Quanti-Tray system. After 24 hours of incubation, the water treated by the Solar Powered UV-C LED Water Sterilizer showed a significant decrease in coliforms, Escherichia coli, and turbidity compared to the untreated pond water. These findings propose that the Solar Powered UV-C LED water sterilizer treated water so that it may be potable. In the future, the Solar Powered UV-C LED Water Sterilizer may be utilized in communities that lack traditional water services, and components of the device can be replaced with more sustainable options to reduce overall cost and environmental impact.

Keywords: Mobile water sterilization, Solar-powered UV-C LED technology, UV-C LED water sterilizer, Sustainable water purification

The Impact of Existing Coastal Defense Structures on Flood Prevention due to Climate Change

Sophie Myung

Coastal flooding causes detrimental consequences, threatening infrastructure, biodiversity, and human lives. In past decades, the United States has witnessed an increasing rise in sea levels due to climate change, making coastal areas more susceptible to such damage. Coastal flooding causes billions of dollars in damages, on average, the United States sustains 120 billion dollars in damages each year and this amount continues to increase. Due to this, communities across the nation install flood walls, which act as a barrier against devastating ocean waves. Overall, this project's goal is to determine the effectiveness of coastal flood walls considering the repercussions of climate change such as rising sea levels . This research highlights the need for not only improved up-to-date flood prevention structures, but additionally focuses on the increasingly violent effects of climate change. The procedure consists of placing three different flood wall replicas in a wooden flume filled with water. From there, waves are generated by a wedge-shaped plunger mechanism. Each test will be documented and later reviewed to determine that structure's effectiveness at redirecting/stopping the water. The parameters of the experimentation were determined based on a real occurrence on January 14, 2024, in Salem, MA, in which a large storm surge caused severe coastal flooding and the failure of a seawall. The purpose of this experiment is to make pivotal strides in determining the effects of climate change on coastal flooding and give way for improved designs in the future to protect onshore communities.

Improving Size Control Following Hydrothermal Synthesis Preparation of Carbon Quantum Dots

Caitlin Riordan

Esha Bhawalkar

Findlay Toone

This research explores the enhancement of size accuracy in the centrifugation of carbon quantum dots through the incorporation of a polyvinylidene fluoride (PVDF) filtration layer within the centrifuge tubes. PVDF, known for its resilience in high-temperature, acidic, and radiative conditions, is utilized as the ltration material. The study involves the determination of the desired quantum dot size, approximately 10 nm or less, followed by the creation of lter perforations using laser ablation methods. Subsequently, quantum dots undergo centrifugation at approximately 1,000 rpm, and their size distribution is assessed using dynamic light scattering (DLS). This technique, commonly employed for measuring size distributions, is adapted for potential application in evaluating quantum dot sizes. The proposed methodology aims to improve precision in quantum dot size control through innovative centrifugation and filtration techniques.

Investigating Plant Combustability Under Varied Moisture Levels

Sary Khir

Time to Ignition:
The data shows that the time to ignition varies among different plant species and moisture conditions . Generally, drier plant samples tend to ignite more quickly than those with higher moisture content. This indicates that moisture plays a significant role in the ignitability of plant materials. Aloe vera, Bamboo, and Lavender all exhibit this trend, with shorter ignition times observed in the dry condition compared to the moderate and wet conditions.
Time Until Combustion:
After ignition, the time until combustion also varies depending on the moisture content of the plant samples. Drier samples tend to burn for a longer duration compared to moister samples. This suggests that moisture acts as a barrier to sustained combustion. However, it's noteworthy that the time until combustion is generally shorter than the time to ignition, indicating that once ignited, even moister plant samples can burn relatively quickly.
Weight Loss During Combustion:
The percentage of weight loss during combustion provides insight into the combustibility of different plant species under varying moisture conditions. Consistently, drier plant samples exhibit a higher percentage of weight loss compared to moister samples. This confirms the relationship between moisture content and combustibility, with drier materials burning more easily and completely.
Conclusion:
In conclusion, the experiment provided insights into the relationship between plant moisture content, humidity levels, and combustibility. While the hypothesis correctly anticipated that decreasing plant moisture levels would enhance combustibility, it somewhat underestimated the influence of humidity on combustion behavior. The results revealed that drier plant samples ignited more quickly and sustained combustion longer, underscoring the critical role of moisture content in determining combustibility. Additionally, the experiment highlighted the complex interplay between environmental factors and plant characteristics, with humidity levels also impacting ignition behavior. These findings contribute valuable insights to wildfire management strategies, emphasizing the importance of considering both plant moisture content and environmental humidity levels in fire prevention efforts.

Alternative Roof Surfaces to Combat Urban Heat Islands

Keira Madden

Buildings within cities all seem to have the same style of roof that is dark bland colors that absorb the heat of the sun without anyone noticing. Is there a way to change the roofs to provide a more comfortable living environment for the occupants inside? If there is, what sort of alternatives are there? Additionally, can the roof material make the temperature consistent? During this experiment, 4 different styles of roofs, black, white, solar, and garden were tested to discover which roof had the best internal temperatures within the boxes. This experiment revealed the trend that the temperature outside affects how warm the inside temperatures of the boxes will be. After performing the test it was found that there is a significant difference between the time of day the data is taken and the external temperature affecting the internal temperature. With the fluctuation of the external temperature each week it proved to be significantly making a difference in the temperature data. While this experiment may only have been performed with limited materials in the future it could be expanded to using legitimate roofing materials and fully functional solar panels.

Fish+Food=Science of Aquaponics

Kallia Piso

In this experiment, an aquaponics system was created to determine the best method of approaching the increasing issue of world hunger. This brings the question: How can an aquaponics system be cultivated globally to prevent hunger to feed the growing population by 2050? In an aquaponics system, plants grow the most efficiently as opposed to other traditional growing methods. In this experiment, materials gathered to create an engineered Nutrient Film Technique (NFT) aquaponics system will effectively produce lettuce that is high quality, efficient in quantity, and grown quickly. It will be compared next to a soil-based method of growing the same number of lettuce seeds to highlight the differences. The results of this experiment showed lettuce that was produced to a height of up to seven inches in six weeks compared to a soil-based method that grew four inches, where the aquaponics system lettuce weighed more, portrayed a higher vibrancy in color, and grew almost double the time of the soil-based method. The hypothesis was supported in this experiment, as the results showed more efficiently grown lettuce.

Bionic Earthworm Water Dowsing Robot

Bocheng Huang

The inhospitable nature of desert terrains presents a significant challenge for traditional mobile robots , primarily due to their reliance on wheels or tracks that are not well-suited for navigating through soft, uneven, and obstacle-ridden sands. This limitation severely hampers their ability to move efficiently, let alone perform tasks such as the detection of underground water sources—a critical need in arid environments. Moreover, ground and aviation robots fail to penetrate the ground deeply enough to provide accurate or useful data on water sources; crawling robots seem to be the best solution for this task.

While current studies have innovated crawling robots that achieve simple motion in flat and tunnel environments, they often struggle with precise control and moving underground. Addressing these challenges, this study focuses on searching for underground water in desert areas and introduces an earthworm bionic water searching robot that can travel underground, with an imu (accelerometer) and humidity sensor to monitor the robot’s position and navigate water sources in various environments.

After five different designs and two prototypes, the latest version features an earthworm-like muscle structure composed of silicon-based radial and tube muscles. Five muscles are actuated by air pumps delivering both positive and negative pressure, enabling them to perform a broad range of movements. Two radial muscles act as anchor points, enhancing friction, while the tube muscles achieve flexion and extension.

Controlled wirelessly via Bluetooth, the robot utilizes acceleration, pressure, and humidity sensors integrated with an Arduino platform for monitoring the robot's location underground and precisely controlling ten solenoid valves directing and facilitating the robot's movement by modulating the muscle tubes' contraction and expansion to perform crawling and directional changes under desert environment. The final version is about 20 cm long and able to move 2.5mm per second in sand.

Keywords: Bionic robots, Earthworm locomotion, Search and rescue, Water detection.

A model using tidal power to slow down or cease salt intrusion

Mabel Lam

Salt wedge is the process by which a distinct layer of saltwater forms below a layer of freshwater due to differences in density. Salt wedge is the result of weak tidal currents that can not mix the salt water into fresh water. Besides, it has negative effects on lands and humans. This natural phenomenon directly damages plants by accumulating chloride and sodium ions in plants. They can also create a kind of chemical drought where water in roots can diffuse out into the saltier soil. If plants are actively growing, these effects will cause greater damage. The longer plants experience salt water inundation the greater the toxicity. When they consume food, it will have a higher salt ratio in humans' diet. This undermines humans' health negatively. Acknowledging this issue, this research is conducted to tackle or prevent the salt wedge, particularly to sustain planting and protect human's health. The experiment is a crucial part of this research. It includes the stimulation of salt wedges by separating fresh water and salt water in a fish tank with a great difference of temperature and the concentration of salt (about 9%) . To distinguish freshwater and saltwater, different coloring is used for fresh and saltwater. Using and designing our model as a submersible motor to generate the tidal wave to push and slow down the flow of salt water into fresh water. After conducting the experiment, the salinometer is used to measure the salinity level of fresh water and salt water. Subsequently, if the salinity level of fresh water and salt water slightly changes, the experiment supports the hypothesis (that the motor creating tidal waves is able to slow down the process of salt water intrusion) and vice versa.

Advanced 3D Deep Transfer Learning for Multistage Alzheimer's Disease Diagnosis

Alex Kuai

As of 2020, there were around 50 million people worldwide with Alzheimer's disease (AD). [1] It most often begins in people over 65 years old, but up to 10% of cases are early-onset impacting those in their 30s to mid-60s. [2] [3]. Current diagnosis of AD heavily relies on manual inspection of brain atrophy using medical images, including non-invasive structural magnetic resonance imaging (sMRI), which is challenging and time-consuming for clinicians due to subjectivity and precision issues. Robust and rapid diagnosis of AD, particularly at early stage for mild cognitive impairment (MCI), is urgently needed. sMRI scans contain many slices as 2D images stacked together to form a 3D volume. A pure AI deep learning 3D convolution for 3D medical image analysis is huge drawback due to lack of large-scale universal 3D image pretraining and extremely complexed 3-D medical images.

This research focuses on the development of advanced 3D deep transfer learning for multistage AD diagnosis, through an innovative set of approaches: 1) A cascade of data methods for sMRI image preprocessing and a U-Net semantic segmentation identified the crop-sized region of interest (ROI) containing the largest lateral ventricle volume, facilitating the model to focus on relevant information with reduced training time and computational cost. 2) A pretrained weights on 2D ImageNet of more than 1 million natural images from public repository [4] were transferred into a 3D convolutional neural network (CNN) of RGB dataset of sMRI ROI. (3) A deep transfer learning architecture VGG16 was modified with additional normalizations, dropouts, and training hyper-parameters. The trained deep learning model was evaluated by performance metrics including loss, accuracy, recall, precision, AUC-ROC (area under the curve of receiver operating characteristics) and proved as a generalizing model cross the sets of training-validation-testing, should be sensitive for unseen data prediction. This AD multistage classifier was further evaluated by One-vs-the-Rest (OvR) ROCs and confusion matrix, proving an overall high precision model in predicting MCI and AD together and excellent recall sensitivity (94%) in predicting MCI, which is clinically crucial for early and accurate diagnosis of onset of AD with mitigated false negative rate. Deep learning techniques like this have the potential to assist clinicians to diagnose AD and MCI by providing rapid and objective analysis.

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Shuffle Science: Analyzing Machines, Riffles, and Algorithms in Card Shuffling

Jamison Ballou

Card shufflers around the world face a great dilemma: whether to invest in an automatic shuffling machine for possible advantages in randomizing the deck, or to shuffle by hand for more direct control. Much research has been done on shuffling machines and the riffle shuffle (the most common shuffle, where the shuffler runs their thumbs up two cuts to interlock them), and most agree that seven riffle shuffles or several runs through a shuffling machine is sufficient. This study investigates whether riffle shuffles or shuffling machines generate a higher entropy (the mathematical measure of randomness) more quickly, and how algorithms that simulate shuffling compare to these two and each other. To test this hypothesis, ten shuffles of each the riffle shuffle and shuffling machine were performed ten times; additionally, each algorithm, one from Random.org, one from a TI-84 calculator, and one from a python random number generator program, was tested twenty times. The results showed that the automatic shuffling machine and riffle shuffle were very similar, but the riffle shuffle slightly edged out the machine. The three algorithms tested were very similar (the most random was from Random.org), and slightly beat the riffle shuffle and shuffling machine. The best option for creating the highest entropy in a deck of cards is to use the riffle shuffle.

On the Properties of Quadrilaterals Determined by Triangle Centers

Ganghun Kim

The diagonals of a convex quadrilateral determine four triangles. Within each such triangle select a triangle center (e. g. incenter, centroid, circumcenter, orthocenter, etc.)

These four centers define a new quadrilateral. Is there something interesting that can be said about this quadrilateral? What if the initial quadrilateral has some particular property (e. g. it could have been cyclic, tangential, orthodiagonal, equidiagonal etc.) Does that property transfer to the central quadrilateral? Or maybe the central quadrilateral enjoys some other property?

This type of problem has been considered before, with origins that could be traced as early as 1850's. However, until very recently the research was limited to the case when the centers were among the ones every high school student is familiar with: incenter, centroid, circumcenter, and orthocenter.

In 1993 Clark Kimberling extended the notion of triangle center to a much wider class of points which can be associated with a triangle. There are currently more than 61,000 such entries in the online Encyclopedia of Triangle Centers (ETC).

Intuitively, if one performs the same geometric construction (or sequence of constructions) for each of the vertices of a given triangle and the outcome of this process is a single point, then we call this point to be a triangle center.

In a very recent paper, Rabinowitz and Suppa investigated the first 1000 centers listed in ETC in the context of the original quadrilateral question and discovered a wealth of new results. In our research we find simpler proofs of some of their statements and discover some new results by considering triangle centers which Rabinowitz and Suppa never considered or simply missed.

For example, one of our results is the following:

Let ABCD be a convex quadrilateral. Let O1, O2, O3, and O4 be the circumcenters of the four triangles BCD, CDA, DAB, and ABC, respectively. Likewise, let N1, N2, N3, and N4 be the 9-point centers of the same triangles. Then O1O2O3O4 and N1N2N3N4 are similar convex quadrilaterals with opposite orientations.

Energy-Efficient Egocentric Video Recognition

Derek Jin

Just like how observation is the foundation of human learning, egocentric video recognition extracts useful information from raw video data captured by cameras worn by the subjects themselves (first-person) and trains the computer to perform tasks normally done by humans. It is crucial in many industries from autonomous driving to augmented reality/virtual reality. However, compared with audio or text, videos are much more complex to analyze and traditional video recognition models have little success in real time, real world applications. In addition, there have been mounting concerns about the massive amounts of energy that video recognition equipment consumes. EfficientViT, pioneered by researchers at MIT Han Lab in September 2023, is a fast and lightweight model that can train computer vision at high resolution on daily devices. However, currently EfficientViT is only for images. My work extends EfficientViT from image processing to video recognition, using EPIC-Kitchens, an egocentric video dataset. My model can make predictions in real time (milliseconds) and its accuracy is 600 times better than random guesses.

Relation Between Nuclear Power Plants and Childhood Cancer Deaths

Brenna Duffy

Teagan Tierney

Previous studies disagree about whether exposure to harmful ionizing radiation present in NPPs (NPPs) can increase the risk of cancer in nearby residents. We examined whether persons ages 0-24 who live in counties with an NPP have a higher risk of dying from cancer. In this study, data was collected from CDC Wide-ranging Online Data for Epidemiologic Research (WONDER) and the US Energy Altas and was prepared for analysis by selecting 50 counties with NPPs and 50 Control Counties that had similar urbanicity and regions. Urbanicity and region were found using the 2020 US Census. In a separate analysis, control counties were matched on average per capita income, obtained from the Bureau of Economic Analysis. We then used the CDC WONDER database, selecting deaths from International Classification of Diseases 10th Edition (ICD-10) codes C00-C97 (“malignant neoplasms”) between the years 1999 and 2020. Analyses were performed overall and in subgroups by urban versus rural and low versus high income. Then groups were compared using T-tests comparing rates per 100,000 people. Although there was no significant difference in deaths due to cancer in counties with NPPs vs without , in the overall cohort and rural, urban, and high-income subgroups, there was a significantly higher rate of cancer deaths in low-income NPP counties compared to low-income non-NPP counties (OR, 95% confidence interval, 1.17 (1.00-1.36), P value 0.02). Further research on this topic might examine person-level data and incorporate cancer incidence, not just mortality.

Can Antidepressants Reduce the Risk of Psoriasis?

Aadya Goel

Investigating the potential link between antidepressant usage and psoriasis risk, my study utilized real-world patient data to shed light on this complex relationship. Psoriasis, a prevalent autoimmune condition impacting millions globally, has long puzzled researchers. While its precise cause remains elusive, emerging evidence suggests a possible connection between antidepressants and susceptibility to psoriasis. Using the All of Us online program, I analyzed real patient data to explore the link between antidepressants and psoriasis risk. Examining patients who took antidepressants and developed psoriasis, I also considered demographics such as ethnicity, race and age to identify the most affected groups. Common antidepressants among patients with psoriasis included trazodone hydrochloride, sertraline, and duloxetine. Notably, users of nefazodone exhibited over a 10% risk of psoriasis. Moreover, individuals above 65 or of Asian or White ethnicity seemed most impacted. This suggests antidepressants may elevate psoriasis risk, consistent across demographic groups and antidepressant types. I developed a RandomForest model with a 67.3% overall accuracy, predicting psoriasis occurrence based on age, race, ethnicity, sex at birth, antidepressant type, and duration of usage. This model categorizes users by antidepressant type and duration of usage, offering valuable insights. Future research regards looking at ways to optimize this model and making it more accurate. Additionally, looking at other factors that could have influenced my data, such as genetics, or other drugs the user may have been taking.
Keywords: Antidepressant usage; Psoriasis risk; Real-world patient data; Demographics; Predictive modeling; RandomForest model;

Finding Early Dementia Predictors: Survival Analysis Utilizing Sleep Electroencephalogram and Blood-Based Biomarkers

Zachary Chen

As the world develops into more technologically advanced societies, the average life expectancy has risen. As a result, dementia has become the 7th most common reason for death. However, due to Dementia's long preclinical phase, worldwide, it is estimated that 41 million individuals with dementia remain undiagnosed. It is, thus, imperative to diagnose Dementia earlier in order to allow patients to gain access to quality care that can slow down the progression of the disease and increase quality of life. Our research utilized the Framingham Heart Study (FHS, n=4998) and overlapped it with the Sleep Heart Health Study (SHHS, n=5839) to create a new dataset (n=604) with patients containing both sleep signal and biomarker data. After removing patients without APOE-ε4 status, and adjusting for covariates, our new dataset had a size of n=372. The theory behind this methodology focused on two major factors contributing to dementia: brain activity during sleep and blood biomarkers. Sleep takes ⅓ of lifetime, and contains rich information about brain health. We utilized novel microstructure patterns measured through electroencephalogram (EEG), which measures electric signals from the scalp. The patterns include sleep spindle characteristics, and multi-taper spectral estimation to calculate band power during non REM and REM sleep at delta (1-4Hz), theta (4-8Hz), and alpha (8-12Hz) bands. Separately, we looked at blood-based biomarkers—a factor directly reflecting the inflammatory, metabolic, and many other biological functions. The blood biomarkers include tau, amyloid-β 40 and 42, and neurofilament light chain (NfL). We conducted four Cox Fine-Gray survival analysis with death as competing risk utilizing two different tests of tau, amyloid beta, neurofilament light (NfL), and adjusted each test with covariates age, sex, bmi level, education level, smoking status, and APOE-ε4 concentration. A backward forward selection Akaike Information Criterion (AIC) was utilized on the sleep signals to create the best model accounting for model complexity and best fit. Then, we performed Area Under the Receiver Operator Characteristic Curve (AUROC) to compare the Cox Fine-Gray models to the AIC model, finding that the AIC final sleep signal model was the best model with an AUROC score of 0.93 by year 10 in the survival analysis while the worst performing model was the Aβ 42/40 ratio model with a AUROC score of 0.87. By year 20, our model predicts a 60 year old female patient with poor sleep would have a 16% of developing dementia compared to a 60 year old male patient with poor sleep who would only have a 4% of developing dementia while keeping other variables constant.

Dancing with Math: Using Klein’s Quartic for Music Generation

Jiuzhou Chen

While music theory and mathematics may seem like two disparate worlds, attempts to connect them have been made since the 19th century, when Hugo Riemann constructed his models. By representing a musical tone, the simplest unit in music, as a vertice, and the transformations between the tones as edges, Riemann constructed an infinite graph of triangular tessellations. Neo-Riemannian musicologists such as Richard Cohn and Brian Hyer have generated many such “tone networks” in order to analyze and generate music. In the same spirit, this study examines a potential tone network, the Klein quartic, and attempts to find its applications in music. The Klein quartic has 24 vertices, corresponding to the 24 major and minor triads generated by the twelve tones of western music, one major and one minor triad generated for each tone. This study first backgrounds modeling in music theory, then examines the properties of the Klein Quartic, explaining how triads can be mapped onto its vertices, then uses the Klein quartic framework to analyze The Imperial March from “Star Wars”. We hope that models such as this one will one day lead to the full realization of how music is constructed and give complete understanding of the mystical art that we call music.
Keywords: music theory, Neo-Riemannian Analysis, Klein’s quartic, group theory, abstract algebra, hyperbolic geometry

Analysis of Gene Expression in Cell Lines with Altered VPS35 Gene Expression

Larry Zhang

Parkinson's Disease (PD) is a neurodegenerative disorder that affects about 1% of human beings over 60 years old. While there are treatments for specific PD symptoms, there are currently no cures. Vacuolar protein sorting 35 ortholog (VPS35) encodes a core component of the retromer complex, which is responsible for regulating and sorting proteins within the cell.

A mutant form of VPS35 (D620N) has been unambiguously linked to familial PD in numerous PD patients. Understanding D620N's functions and effects on human cells is therefore crucial in the battle against PD. Currently, specific cell disorders resulting from D620N have been observed, but the role of D620N in the pathogenesis and development of PD is not fully understood. My project compares the effects of D620N with the effects of various concentrations of VPS35, across 800+ probes, to gain an increased understanding of the functions of D620N. After learning the background and understanding the previously gathered raw data, I leveraged Python programming and Google Sheets to first normalize and filter the data. Then, I analyzed the data by calculating correlations and multiple statistical distance functions using Python. My conclusion from the analysis is that the D620N mutant is most similar to normal VPS35, as compared to knockdown or increased concentration of VPS35. This suggests that the mutant's functions are dissimilar to altering the VPS35 concentration in the cell. In the future, we can test other changes in VPS35 and compare results to the mutant form to potentially lead to a better understanding of the mutant's role and functions.

Astro-Seismic Prognostication using Planetary Position, Historical Earthquakes and MATLAB-based Machine Learning

Ragav Iyer

Io is a volcanic moon and the most geologically active object in the Solar System. Scientists have long known that Io's extreme geologic activity is caused by the gravity of Jupiter and several other moons acting on Io's interior. Yet, if gravity and the positioning of celestial bodies can have such a dramatic impact on the geological activity of Io, could the same be true of the geological activity on Earth?

The World Health Organization (WHO) estimates 750,000 global deaths from 1998 to 2017 due to Earthquakes – more than half the casualties from all natural disasters. For decades, scientists have been extremely limited with regards to their ability to predict earthquakes, with the United States Geological Survey stating "[n]either the USGS nor any other scientists have ever predicted a major earthquake. We do not know how, and we do not expect to know how any time in the foreseeable future."

Linking together these two scenarios results in the obvious question: Is the celestial positioning of solar system objects related to the occurrence of earthquakes? Can said celestial positioning data be used to predict characteristics of earthquake occurrence such as magnitude, location, or dates? It was hypothesized that, as supported by evidence of celestial positioning impacting the geological activity of other bodies in the solar system and several recent studies indicating a correlation between earth tides (influenced by lunar position) and certain earthquakes, the celestial positioning of solar system objects is related to earthquake occurrence. Moreover, due to the predictable positioning of such objects, it was further thought that they could be used to predict key characteristics of earthquake occurrence.

To satisfy the predictive and analytical demands of this study, machine learning models were employed to find the existence of such a correlation and predict key characteristics of earthquake occurrence. Specifically, the successful development of an earthquake prediction utility and subsequent statistical analysis at the end of an iterative, machine learning workflow appears to validate components of the design hypothesis, demonstrating the clear existence of a planetary position - earthquake relationship. Statistical analysis of model performance and residuals Astro-Seismic Prognostication using Planetary Position, Historical Earthquakes, MATLAB-based Machine Learning demonstrates that such an approach is particularly useful for small earthquake magnitude, earthquake occurrence, and -- to a limited degree -- location predictions.

Analyzing HLA sequences to Predict Organ Rejection and Find Targets for Precise Immunosuppression

Samhitha Bodangi

Organ rejection is a dangerous medical complication that can occur after an organ transplant. Currently, all transplant patients are prescribed life-long immunosuppressors to decrease the risk of organ rejection. However, these medications can increase the susceptibility to other infections and cancers. Human leukocyte antigen (HLA) mismatches between donors and recipients can initiate T-cell activation, which is known to be the primary mediator of organ rejection. However, HLA genes are very polymorphic, and classifying “whole” HLA mismatches does not account for the allele differences that can start rejection. One solution is to create a machine-learning model that can analyze donor and recipient HLA sequences to predict MHC-peptide complexes, which are the molecules that T-cells recognize to start an immune response. This information can be used to predict rejection and find precise targets for immunosuppression. The project used datasets with MHC class I-peptide binding information to analyze donor and recipient HLA sequences. The expected result is that the model can accurately predict MHC-peptide complexes and rejection targets. In conclusion, focusing on MHC-peptide presentation can account for HLA polymorphism and is more accurate in predicting organ rejection. Additionally, this data can be used to administer personalized and targeted immunosuppressors or decrease the need for broad immunosuppressors altogether. A similar model can be developed to predict antibody-mediated rejection (AMR) using MHC-class II datasets and modified to support other organ transplants.

Can You Create Waves By Clapping?

Om Sharma

Physics is everywhere in this world. To make Physics interesting, it is important to find some interesting examples of activities that everyone does in their daily life, specifically when you are happy or appreciate someone and cheer for them by clapping shows Physics.

Waves are one of the important concepts in Physics. A wave is a disturbance in the medium that is produced by a repeated back-and-forth motion and carries energy from one place to another. Waves are everywhere. I thought clapping could be a good example to use as a project for this year's science fair to show how wave concepts are involved in it . To understand what Physics is behind clapping, it is important to know how waves are created by clapping. In this project, I also would like to show how types of waves e.g. sine waves, and cosine waves can be created by clapping. How loudness and fast clapping can show properties of amplitude and frequency. How interference can be explained by clapping. These are fascinating ways to study the concept of waves by clapping.

It’s Not Rocket Science! The Effects of Varying Quantities of Water in Water Rocket Launch Altitude

Benjamin Davis

This project aims to get children interested in rockets and the physics behind them , to show how learning science can be fun. The hypothesis was if there is more water used in a bottle rocket, then the bottle rocket will go higher because it has more mass to expel and propel the rocket in the opposite direction. This experiment began by constructing a launch rig and launcher for launching bottle rockets. Then, the rockets themselves were created. Next, three launches were performed, using 80 psi of air pressure, with 0 mL of water, 50 mL, 100 mL, 150 mL, increasing similarly until reaching 1000 mL of water. The results were then graphed and analyzed. The expected outcome was that there would be a steady increase in launch altitude with an increase in water volume. The significant results from this experiment are that, as expected, the launch height increased while going from 0 mL of water used to 550 mL of water used; however, the launch height decreased from 550 mL to 1000 mL. The average altitude over three launches with 0 mL of water was 28.55 meters. The average altitude over three launches with 550 mL of water was 69.19 meters, and the average altitude over three launches with 1000 mL of water was 61.26 meters. Some of the rockets did not launch the same as others, even though they were constructed the same. There is no immediate explanation for this yet.

Observing the Visible Spectrum through the Interference of Water, Isopropyl Alcohol, and Acetone

Belle Li

The behavior of light was observed as it was refracted with a prism and through different liquids in order to determine how the visible spectrum's area was affected. It was predicted that the area of the visible spectrum would increase by passing through all liquids. A triangular prism separated the beam of light into the spectrum, and a glass cup with the liquid, which could be water, isopropyl alcohol, or acetone, was placed in its path. The image of the visible spectrum is then observed and measured on the opposing screen. The prediction was contradicted by the results of the experiment, where the spectrum through the interference of the empty glass cup had the highest average area,72.5 cm2, while the spectrum through acetone had the lowest average area, 59.3 cm2, though errors in consistency may have affected the data. This experiment can be used as an example or demonstration of certain optical properties and laws, such as Snell's law.

Dusty Plasma

Robert Simpkins

In this experiment, I investigated how dust affects the voltage required to create plasma, specifically charged dust particles. In order to test this, I created plasma between a spark plug powered by a neon transformer and a copper wire both located in a vacuum chamber. My hypothesis was that it would be easier to form plasma when there were charged dust particles inside of the vacuum as they were less stable and easier to ionize. In plasma, all of the atoms are fully stripped of their electrons and the electrons are shared throughout the plasma. However, during experimentation, we found that the presence of dust particles drastically increased the voltage required to form plasma. Due to safety constraints, there was a limit to the voltage we could use, and because of this we do not know exactly how much more voltage is needed to spark with dust or charged dust, we only know that it is at least 50% more voltage. I believe that this could be because of numerous reasons, the density of the dust meant that there were many more atoms that needed to be stripped, so even if it is easier to strip 1 atom it is harder to strip all particles, or that instead of making it easier to strip electrons, adding electrons to a compound makes it harder, as there are more electrons to strip.

Impact of Surface Conditions on the Magnus Effect

Misha Mishechkin

Vishnu Angiras

The Magnus Effect is the tendency of a spinning cylinder or sphere to exert a force perpendicular to the flow of air . This is behind the curve seen in spinning baseballs and soccer balls. This phenomenon was heavily investigated in the early 1900s for airplane and ship propulsion applications thanks to impressive aerodynamic performances. Magnus rotors can even be found on modern-day ships, slashing fuel usage by 30%. However, little is known about how surface conditions influence the effect, an important factor in fluid dynamics that prevents us from harnessing the Magnus effect to its full potential . We sought to revisit this concept. In this experiment, we investigate the impacts of surface roughness and dimple density on a spinning cylinder's aerodynamic performance. We hypothesized that maximizing dimple density and surface roughness would yield the best lift-to-drag ratios, with dimples having superior performance. We find that for both variables, there exists a middle ground for optimal aerodynamic performance. The lift-to-drag ratio of a medium-roughness Magnus cylinder is more than double that of a smooth one in optimal conditions. Dimples only marginally improve lift-to-drag ratios compared to smooth. For ship transportation, our findings can enable fuel and emissions savings of over 50%. As the maritime and aerospace industries struggle to decarbonize, the Magnus effect could be an effective solution for a greener future.

A Novel Hadronization Model for Charm-Quark

Shuhan Luo

The recent experimental measurement on pp collisions at √s =5.02 TeV from ALICE collaboration has shown new results about charm-quark hadronization. The measured baryon to meson ratio Λ_c^+/ D^0 ~ 0.6 is significantly larger than the ones previously measured in ee and ep collisions, and thus indicates the violation of hadronization universality assumption. In this study, a Statistical Hadronization Model (SHM) is applied to explain the charm-quark hadronization process. I consider for the first time the feed-down production from unobserved highly excited states, and those hidden states are incorporated within the SHM calculation. To explain the hadronization non-universality, a scheme of suppression at low volume is included in SHM model. Hence, the production of charm hadrons would depend on the system volume, and the production at smaller collision systems such as ee and ep will be automatically different from production at larger systems such as pp. The results shows that the addition of decay from excited states boost the charm baryon production, the model correctly predicts the Λ_c^+/ D^0 ratio measured by ALICE and provide a Ξ_c^0/ D^0 ratio which is close to the experimental measurement for the first time. With the suppression scheme, the model reveals a sharp decrease in baryon production towards low multiplicity, and therefore successfully explains the non-universality between different systems.