62ND NATIONAL JSHS
JUNIOR SCIENCE AND HUMANITIES SYMPOSIUM

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Abstract Catalog

The abstracts in this publication are from original scientific research conducted by participating students in the 62nd National Junior Science and Humanities Symposium (JSHS) and is the intellectual property of the individual authors listed. For more information and author contact information, please reach out to admin@jshs.org.

JSHS is a Department of Defense sponsored STEM program (U.S. Office of the Secretary of Defense and the U.S. Departments of the Army, Navy, and Air Force) that encourages high school students to conduct original research in the fields of science, technology, engineering, and mathematics (STEM) and publicly recognizes students for outstanding achievement.

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National Junior Science and Humanities Symposium

62ND NATIONAL JSHS JUNIOR SCIENCE AND HUMANITIES SYMPOSIUM

Program Objectives

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

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Section III
Abstracts of Student Papers

Alabama

The Effects of Electrical Stimulation on Planaria Tissue Regeneration

Ashu Anand
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Teacher: Hungsin Chin, Alabama School of Fine Arts

Cellular regeneration is a primary process necessary for the reconstruction of impaired tissue following an injury. In contrast to acute wounds, chronic wounds are characterized by prolonged regeneration leading to an increased susceptibility to infection and potential nerve damage. The role of electrical signals is crucial in initiating regenerative processes integral to wound healing. The objective of this study was to assess the efficacy of external electrical stimulation in enhancing wound healing by facilitating the targeted delivery of electrotherapy to the injury site and promoting the directional migration of regenerative molecules. Wound healing was modeled by the regeneration of bisected freshwater brown planaria. It was hypothesized that planaria exposed to electrical stimulation would have a significantly lower regeneration time compared to unexposed planaria. Electrical current of varying voltage groups (1-Volt, 3-Volts, and 5-Volts) was delivered through a DC power supply in an electrolyte solution. Complete regeneration was measured by the development of prominent photoreceptors in the eye as observed under a microscope. All exposure groups exhibited shorter average regeneration times compared to the control group. A Single-Factor ANOVA statistical analysis followed by a series of Two-Sample t-tests with adjusted Bonferroni correction values confirmed a statistically significant difference between the control group and the 3-Volt group. The accelerated regeneration observed in the 3-Volt exposure group supports that electrical stimulation can enhance wound healing processes after an injury. Future applications of electrotherapy supported by the results of this study may be used to promote tissue regeneration in individuals with chronic wounds.

Localization of Frontotemporal Dementia Risk Gene RAB38 to Glutamatergic Neurons: Implications for Selective Neuronal Vulnerability

Aanchal Behara
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Mentor: Rita M. Cowell, University of Alabama at Birmingham

Frontotemporal dementia (FTD) is a leading type of early-onset dementia caused by progressive neurodegeneration in the frontal and temporal lobes of the brain, resulting in significant alterations in behavior, personality, and language. Neuronal loss predominantly affects the pyramidal cells in Layer V of the neocortex, leading to the death of glutamatergic neurons. This study targeted the selective neuronal death observed in FTD, focusing on pyramidal cells in neocortical Layer V. Utilizing the Human Protein Atlas and online databases, Rab38 emerged as a potential risk gene due to its colocalization with marker genes. To explore Rab38's role in selective neuronal vulnerability, RNAscope in situ hybridization was used to detect the presence of Rab38 and marker genes (Slc17a7 for glutamatergic neurons, Fezf2 for Layer V pyramidal neurons) in mouse tissue. Confocal microscopy and analysis of the slides using Cell Profiler identified Fezf2 and Rab38 in a subset of pyramidal neurons, establishing statistically significant variation in Rab38 and Fezf2 RNA expression between different mice. The relative frequency distribution of Fezf2 and Rab38 pixel densities per cell confirmed the presence of Rab38 in Layer V pyramidal neurons and revealed a higher proportion of neurons with Rab38 but without Fezf2, contrary to initial expectations. Afterward, a comprehensive analysis of the expression levels of Rab38 and Fezf2 was conducted, demonstrating colocalization and a positive correlation. Further investigation into Rab38 expression across low, medium, and high Fezf2-expressing populations in Layer V pyramidal neurons indicated variability in gene expression, highlighting potential influences from technical or biological factors.

Producing Sustainable, Cost-Effective Aluminum-Sulfur Batteries Through a Triple-Function Cathode Design and Anion Charge Carriers

Yiwen Wang
Northridge High School, Tuscaloosa, AL
Teacher: Mrs. Alayna Townsend, Northridge High School

Rechargeable batteries are powering the rise in plug-in electric vehicles and intermittent renewable energy storage/transport/utilization in the electricity grid. With a goal of increasing energy density and reducing production cost, the aluminum-sulfur (Al-S) battery has attracted tremendous interest due to its high theoretical energy density (2981 WhL^{-1}) and the earth-abundant aluminum/sulfur feedstock. However, the lifetime and commercialization of current Al-S battery technology is limited by 1) intrinsic low conductivity of sulfur cathode, 2) polysulfide shuttle effect, and 3) sluggish conversion and transfer of aluminum species in electrolytes. The overall objectives of this project were to (1) design and synthesize triple-function additives of sulfur cathode to mitigate shuttling effect, (2) develop novel chloroaluminate ionic liquid electrolytes with an overall ionic conductivity higher than 5 mS/cm, and (3) elucidate microscopic redox chemistry, transport and charge storage mechanism of chloroaluminate anions ($AlCl_4^-$ and $Al2Cl_7^-$), and their stability challenges in ionic liquid electrolyte-based sustainable Al-S batteries with high performance. These goals were achieved by studying the roles (physical confinement, chemical adsorption, and catalytic effect) of sulfur cathode additives, compositionally optimized chloroaluminate ionic liquid electrolytes ($AlCl_3$ to EMIC ratios: 1.1:1, 1.3:1, 1.5:1) via in situ Raman spectroscopy, NMR, and electron microscopy techniques. This study showed that the synergistic effect of triple-function additives in sulfur cathode can dramatically mitigate the polysulfides shuttle and promote the lifespan (1000 cycles) of Al-S batteries. These results can be transformative in potential applications to electric vehicles and the electricity grid.

The Effects of Pectins on the Copper Ion Concentrations in Water

Bellamy Williams
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Teacher: Hui Li, Alabama School of Fine Arts

This investigation sought to determine the influence of pectins on the copper ion concentration in a copper sulfate solution, focusing on how pectins affect the copper concentration when allowed to soak in that solution for a specific duration. The copper concentration, in parts per million (ppm), was measured using copper testing strips. It was hypothesized that the longer the pectins were exposed to a copper sulfate solution, the more the copper concentration would be reduced. The average copper concentration of the pectins over time between the six trials in the Control, 30 Minutes, 1 Hour, and 3 Hour groups was approximately 1.0, 0.4, 0.3, and 0.2 ppm, respectively. A One-Way Single-factor ANOVA test was run, resulting in a P-critical value that rounded to 0, less than the alpha value of 0.05, implying a significant difference in at least one of the groups of the experiment because the null hypothesis was rejected. A Two-Sample T-Test Assuming Unequal Variances was conducted, followed by a Bonferroni-Significance test to ensure no false positives and determine which groups had significance. All comparisons resulted in a P-critical two-tailed value less than the Bonferroni-Adjustment value of 8.33E−3. Therefore there was significance between Control and 30 -Minute groups (P-Critical:1.22E−11), Control and 1-Hour groups (P-critical:3.48E-12), Control and 3-Hour groups (P-critical: 3.56E−12), 30-Minutes and 1-Hour groups (P-critical: 1.08E−11), 30-Minutes and 3-Hour groups (P-critical: 2.10E−11), and 1-Hour and 3-Hour groups (P-critical: 2.70E−7). As a result, the hypothesis that the pectins would be able to reduce the copper concentration of the solution was therefore supported.

Smart Assistive Senior Care

Edwin Wu
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Mentor: Yue Cui, Auburn University at Montgomery

Senior people living at home or in senior apartments face many challenges, such as the need of at-home incident detection, notification, and assistance; being unable to take correct medication on time; forgetting meals; or having difficulty using utensils due to trembling hands, etc. To overcome their main adversities, I have developed a kit to help them to conquer above mentioned challenges. The kit has two sections: enhancing safety and facilitating life.

Alaska

Optimizing hypoxia and reoxygenation protocol to study the molecular mechanism of oxygen-glucose deprivation resistance phenomenon in Arctic Ground Squirrel Neuron Progenitor Cells

Priscilla Wang and Julia Wang
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Teacher/Mentor: Dr. Kelly Drew and Vy Nguyen, University of Alaska at Fairbanks Biochemistry Department

This paper measures neurons' viabilities after hypoxia and reoxygenation to optimize the protocol for Arctic Ground Squirrel Neuron Progenitor Cells (AGS NPCs), which can survive oxygen and glucose deprivation (OGD) - in-vitro model of ischemic stroke. Human neuron progenitor cells, however, are unable to sustain OGD like AGS NPCs. This OGD resistance phenomenon in AGS NPCs can be applied to treat ischemic stroke although its underlying mechanism is not well understood. To study the phenomenon, we need a working hypoxia-reoxygenation protocol (referred to as hypoxia protocol from this point in the paper), which means that there is a significant decrease in viability after treatment. Therefore, we have obtained N2A mouse neuroblastoma cells to test our hypoxia protocol. N2A was expanded and differentiated following AGS NPCs expansion and differentiating protocol, then the experimental group was put in a hypoxia chamber for 24 hours, followed by reoxygenation for 24 hours. An Alamar Blue assay was done for both control and experimental group 3 times: before the hypoxia treatment, 24 hours after the hypoxia treatment, and 24 hours after reoxygenation. Our hypoxia treatment results in significant decrease in cell viability which implies significant cell death after reoxygenation period. Though an additional cell death assay must be done to quantify the cell deaths caused by our hypoxia protocol, the successful result coming out from this experiment means that we can use this protocol for rat neural stem cells and AGS NPCs for the study to investigate the role of neurogenesis in AGS NPCs OGD resistance.

A Potential Method of Spacecraft Touchdown with Magnetic Induction for Future Space Travel

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With the rapid development of space technology, it is clear that space travel and even space settlement will become a part of our daily lives. As I observed how a magnetic ball quickly slows down and reaches a low terminal speed as it falls through a copper pipe, I wondered whether I could use this same magnetic resistance mechanism for spacecraft touchdown.

To study magnetic resistance, first, I conducted experiments to find the terminal speed and falling speed of the magnetic ball through the copper pipe. Next, based on Newton's law and using the Euler-Herun method, I created a simulation to investigate the motion of the magnetic ball falling through the pipe with magnetic resistance. The comparison between my simulation with the experimental data shows that my simulation is reliable. Based on the tested simulation code, I studied the touchdown process with a designed lander and landing tube. The results show that my landing method is simple, effective, and quite promising for future space travel. To further test the method, I have been building a small-scale prototype of the lander and landing tube. I will also study how currents, the shape of the landing tube (especially in a funnel shape), and the soil material on the moon under the landing tube affect the touchdown process through my simulation.

Arizona

Fairness in Autonomous Driving: Towards Understanding Confounding Factors in Object Detection Under Challenging Weather

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Advisor: Professor Ransalu Senanayake, LENS Lab, Arizona State University

The deployment of autonomous vehicles (AVs) is rapidly expanding to numerous cities. At the heart of AVs, the object detection module assumes a paramount role, directly influencing all downstream decision-making tasks by considering the presence of nearby pedestrians, vehicles, and more. Despite the high accuracy of pedestrians detected on held-out datasets, the potential presence of algorithmic bias in such object detectors, particularly in challenging weather conditions, remains unclear. This study provides a comprehensive empirical analysis of fairness in detecting pedestrians in a state-of-the-art transformer-based object detector. In addition to classical metrics, we introduce novel probability-based metrics to measure various intricate properties of object detection. Leveraging the state-of-the-art FACET dataset and the Carla high-fidelity vehicle simulator, our analysis explores the effect of protected attributes such as gender, skin tone, and body size on object detection performance in varying environmental conditions such as ambient darkness and fog. Our quantitative analysis reveals how the previously overlooked yet intuitive factors, such as the distribution of demographic groups in the scene, the severity of the weather, and the pedestrians' proximity to the AV, among others, affect object detection performance.

The Function of p53 in Intestinal Epithelium Wound Healing

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The intestines are a crucial part of the digestive system, aiding in digestion and nutrient absorption. They feature a columnar barrier of intestinal epithelial cells, called the intestinal epithelium, that is responsible for absorbing nutrients and defending against antigens. The barrier possesses unique regenerative processes that renew its lining every 3-5 days, whilst maintaining almost identical cell structure and cell type ratio. The intestinal epithelium is studied for its role in stem cell nodes and monolayer development regarding cell signaling and intestinal epithelial wound healing. The tumor suppressor gene, P53, has been linked with leader cell behavior during cell migration in MDCK monolayer development. Through study, we observed

the function of p53 during intestinal epithelium wound healing, with the GiLA1 organoid line and p53-mNeonGreen and H2B/iRFP protein trackers. A live-cell imaging movie encapsulated the development of the organoid monolayer and was further analyzed through automated cell tracking. Immunofluorescent staining for Ki67 was used to compare the protein expressions within various cell types. We observed three transient and unique p53-positive cell types during wound healing. One of these types displayed a canonical p53 response, suggesting a different role for the other subtypes. We identified $p53^{WAR}$ (Wound Associated Repair) cells as essential leaders of collective cell migration during wound healing. We further discovered localized p53 in Ki67 high cells originating from the stem cell nodes. Lastly, most Wound Associated Epithelial (WAE) cells were p53-negative but showed a transient increase in p53 after wound closure, suggesting a role for p53 in re-differentiation.

A-BiRD: Automated Bird Recognition Device — Revolutionizing Ornithological Research for Global Bird Conservation

Finnegan McGill
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Mentor: Christopher McGill

The global bird population decline due to climate change, pollution, and habitat destruction is a critical challenge for ornithologists. Addressing this global issue is vital for biodiversity preservation and understanding environmental changes. Reliance on inconsistent, often citizen-sourced data hinders accurate tracking of avian declines. The presence of humans collecting data directly affects bird behavior and produces data of variable quality.

A-BiRD, Automated Bird Recognition Device, addresses these challenges. A-BiRD's data and analysis yields insights into species preferences, nesting locations, habitats, and bird migration patterns without human intervention. It employs Cornell University's BirdNET-Analyzer for identification and cueing, its own algorithm for direction finding, and pandas for data processing, graphing, and analysis.

In a Tucson field study from 09/2023 to 01/2024, two A-BiRD devices successfully collected unbiased data, revealing insights into bird diversity and behaviors during Fall Migration. Accurate species identification and triangulation occurred even with multiple simultaneous bird songs. A total of 98 different bird species and 21,131 combined birdsong events were identified. The study's conclusions highlight changing migration patterns, peak activity periods, and shifts in daily bird species dominance.

Ongoing research and testing are actively shaping A-BiRD into a practical tool. This positions A-BiRD as an innovative device that unites communities in safeguarding global bird diversity. Leveraging Arizona's diverse ecosystems, A-BiRD presently contributes locally, demonstrating immediate impacts on avian research in Southern Arizona. Looking forward, A-BiRD devices hold the potential to address broader environmental challenges, making a significant impact on both local and global bird conservation efforts.

Year 3 Study- Applications of Antimicrobial Bioplastics Engineered from Invasive Algae and Waste Corn Cobs

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Teacher: Alfred S. Santos, Harvest Preparatory Academy
Mentor: Allison Faye Michael

Plastics in the market are produced from fossil sources, like natural gases and coal, which contribute largely to the increase of greenhouse gases and eventually worsen global warming. Thus, there is considerable interest in biodegradable plastics. Current biodegradable plastics pose harm to the environment too; therefore, the purpose of this project is to produce a biodegradable bioplastic from invasive algae and waste corn cobs.

To produce the bioplastic, I extracted the starch from the waste corn cobs, created sodium alginate from *Undaria Pinnatifida,* and combined the ingredients to finally produce the bioplastic. Then, I completed a trial-and-error process to find the right combination of materials that could make the best spoon and straw and measured the bioplastic's qualities through different analyses.

After weighing the bioplastic and the conventional plastic, my bioplastic was able to withhold beyond 2000g, however, the conventional plastic broke at 200g, meaning that the novel bioplastic is stronger. I used a melting station to melt the sodium alginate I extracted and a commercial one and found that the one I extracted melted at 95oC, and the commercial one at 99oC. After weighing and comparing both plastics, I found that the novel bioplastic exhibited 84% biodegradation rate. With the Image J program, I measured the zone of inhibition and found that 80 ml of bioplastic killed 94% of E.coli. In conclusion, the novel bioplastic was more efficient and environmentally friendlier than conventional plastics.

A Rigid-Elastic Hybrid Finger Exoskeleton Rehabilitation System (FERS) for Stroke Patients with Motor Impairment

Brad Wu
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Rehabilitation needs for stroke patients with motor impairment have garnered great attention worldwide. Addressing the limitations observed in existing hand rehabilitation devices, particularly in aspects like Finger Precision, Fine Motor Coordination, and Isolated Finger Movement, as well as mitigating the risk of accidental pain and injury caused by the exoskeleton itself, a novel hybrid finger exoskeleton rehabilitation system supporting the index finger and thumb has been designed and implemented, incorporating the exoskeleton structure and a versatile user interface. Its advantages include precise control of each finger joint, more Degree of Freedom (DOF) and Range of Motion (ROM) movements, pain and injury protection, user-friendly interface, cheaper, and lighter. Noteworthy features include an optimal Multi-bar Serial Linkage with compact Z-shape structure and specialized palm components to reduce size, and elastic elements to alleviate excess force. The hybrid materials used offer advantages from both rigid and elastic components. The 3D-printed exoskeleton structure, inclusive of 6 motors, weighs a mere 300g. Versatile user interface methods, such as GUI Phone App, Mechanical Switch, AI Voice Control, and Computer Vision with Machine Learning which enables preliminary autonomous grasping, have been integrated. Experimental results confirm the successful achievement of all design objectives, showcasing all 7 DOF movements and precise control on each joint and phalanx during rehabilitation training. Performance in practical tests, demonstrating the ability to grasp, pinch, type, and touch, plus 100% repeatability rate and 99.8% accuracy, proves the rehabilitation system's significance in aiding individuals with finger impairment due to stroke and spinal cord injuries.

Arkansas

GlaucoScreen: A Novel Deep Learning Based System for Glaucoma Detection and Progression Monitoring

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Glaucoma, an eye disease that causes damage to the optic nerve, is the second leading cause of blindness worldwide. Swift diagnosis and treatment of glaucoma is crucial to prevent any glaucoma induced vision loss, however this is not usually achievable in developing countries due to their lack of medical resources. This research aims to solve this by creating GlaucoScreen, an inexpensive, accessible system for both reliable glaucoma diagnosis and accurate real time progression monitoring. GlaucoScreen is a system that uses three deep learning models working in tandem with one another to make predictions based on a retinal fundus image. The system first, using U-Net, segments the optic disk from a retinal fundus image. It then analyzes the segmented optic disk with both the glaucoma detection model, which has an accuracy of 97.26%, and progression categorization model, which has an accuracy of 95.88%. These two models utilize InceptionV3. Although there already exist models for optic disk segmentation and glaucoma detection, GlaucoScreen is unique in that it also monitors the progression state of glaucoma which is crucial for its treatment. Additionally, an open-source mobile application and an attachment, which would allow a smartphone to take retinal fundus images, are being developed to be used alongside the deep learning models. In doing so, this research hopes to break down barriers for glaucoma diagnosis and treatment globally.

Mevalonate Pathway Inhibitor GGTi Limits Pancreatic Cancer Cell Proliferation, while Enhancing Normal Endothelial Cell Function

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An estimated 95,389 people are living with pancreatic cancer in the United States. Chemotherapy and radiation therapy are major treatment modalities for pancreatic cancer, but both can cause severe detrimental side effects in the normal tissue that significantly lower patients' quality of life. Mevalonate pathway inhibitors have notably been implicated in the treatment of cardiovascular disease but have more recently garnered interest as potential anticancer agents with minimal side effects. PANC-1 cancer cells were treated with 0, 2, 5, and 10 μM concentrations of GGTi, and proliferation rate was checked using MTT assay. HUVECs were treated with GGTi and generation of activated protein C (APC) was measured by APC generation assay. Finally, radiation sensitivity of PANC-1 cells, following GGTi treatment, was determined by MTT assay. It was observed that GGTi, dose-dependently, attenuated PANC-1 cell proliferation. It was also observed that GGTi significantly enhanced APC generation in HUVECs. Finally, GGTi further enhanced the radiosensitivity of PANC-1 cancer cells. Here, this study reports for the first time that mevalonate pathway inhibitors, specifically geranylgeranyl transferase inhibitor-2133 (GGTi), attenuates pancreatic cancer cell proliferation and enhances radiation efficacy, while augmenting physiological function of endothelial cells. Therapeutically, this indicates that GGTi enhances radio-sensitizing effects in pancreatic cancer cells while also exerting vasculoprotective effects. Therefore, the use of GGTi is a novel treatment strategy for future pancreatic cancer patients.

Elucidating Novel Mechanisms: Berberine Mitigates Cisplatin-Induced Hepatorenal Mitochondrial Dysfunction through Preservation of Electron Transport Chain Integrity

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A high incidence of hepatorenal impairment in cancer patients treated with cisplatin has been reported. Berberine, a plant alkaloid possesses wide range of medicinal properties. Mitochondrial accumulation of cisplatin and subsequent damage to electron transport chain (ETC) plays a key role in the cisplatin-induced cell death. This study was aimed to elucidate the mitigative role of berberine against cisplatin-induced hepatorenal injury with an in depth focus on mitochondrial functions. Clone 9 and Human renal mesangial cells were treated with 10 µM berberine for 24 h followed by 20 µM cisplatin. Cell morphology and intracellular ROS generation (DCFDA), mitochondrial ROS and antioxidant status (RTPCR and Western Blotting), mitochondrial membrane pore transition (Swelling assay), apoptosis (Incucyte), membrane potential (TMRM uptake), respiration and oxygen consumption rate through basal and state 4 respiration (Seahorse Pro analyzer) and protein expression of complex II, III and IV and ATP content were measured. Berberine pretreatment significantly reduced intracellular ROS levels and prevented cisplatin-induced cell death. An increase in mitochondrial oxidative stress and reduced antioxidant enzymes by cisplatin subsequently increased mitochondrial swelling and calcium-induced mPTP opening, apoptosis, mitochondrial membrane depolarization, and inhibition of electron chain complexes leading to reduced oxygen consumption and respiration. Berberine effectively mitigated these deleterious effects, ameliorated mitochondrial functions and prevented cell death. In conclusion, this study has provided significant evidences that berberine preserved the integrity of ETC and mitigated cisplatin-induced hepatic and renal mitochondrial dysfunction. Hence, berberine may be considered as a potential adjuvant drug during and after chemotherapy with cisplatin.

Integrative Assessment of the Novel Radioprotective Efficacy of Cardamonin: A Comprehensive In Vitro and In Silico Analysis

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Current radiobiology research mainly focusses to identify efficient radioprotective agents that can protect normal tissues from radiation-induced injury due to accidental exposures. Recently, cardamonin has gained interest for its potential antioxidant, anti-inflammatory, anti-cancer activity and biosafety properties The main purpose of this project is to decipher the novel radioprotective effects of cardamonin by molecular docking evaluations and in vitro experiments.

Clone 9, HEK 293 and WI38 cells were exposed to 8 Gy gamma irradiation after treatment with or without Cardamonin (5 µM) and cell morphology and intracellular ROS generation (DCFDA) were assessed. Further studies were done in clone 9 cells. Gene (RTPCR) and protein expression (Western Blotting) of Nrf2, HO-1 SOD2, Catalase and GPx were evaluated. Apoptosis was measured by live cell imaging (Incucyte) and protein expression. Molecular docking studies were done with Discovery studio and autodock-vina computational docking software.

Pretreatment of normal liver, kidney and lung cells with cardamonin significantly prevented cell death, and reduced intracellular ROS levels after irradiation. Cardamonin pretreated clone 9 cells significantly upregulated the transcription factor Nrf2 and maintained antioxidant status, which protected the cells against radiation insult. Radiation-induced apoptosis was significantly prevented by inhibiting the activation of caspases 3, 7 and 9. Docking studies revealed the potent anti-apototic, anti-inflammatory and anti-fibrotic efficacy of cardamonin.

In conclusion, cardamonin activated the Nrf2 dependent antioxidant pathway and prevented apoptotic cell death after irradiation. The in vitro and in silico studies provided significant evidence that cardamonin may serve as a promising radiation countermeasure to mitigate radiation injury.

A Holistic Multi-Modal GenAI Healthcare System: Early Detection and Predictive Treatment Monitoring Using Cough Audio and Chest X-rays for Tuberculosis

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Tuberculosis (TB), a bacterial infectious disease, is one of the top 10 causes of mortality worldwide in low-income countries, resulting in approximately 10 million new infections and 1.4 million deaths. Extending on my last year's research, I updated the ML model to include multi-modality (text and audio input) as well as additional feature extraction (mel-spectrograms) and data augmentation (IR-convolution). I created a mobile and web app to integrate the model, and the results are available within 15 seconds. After preliminary testing, the model achieved an area under the receiving operator characteristic curve (AUROC) of 88%, surpassing the World Health Organization's (WHO) requirements for screening tests. I also integrated my new research on chest radiography (CXR) tools. I created a novel 2D convolutional neural network (2D-CNN) to identify and forecast subsequent incident TB using CXR. Predicting the risk of active TB long before symptoms enables preventive treatment that can be administered earlier. This research overviews the data exploration, development, training, and testing of various ML models, and an evaluation of the performance of the optimal ML model. After conducting some exploratory data analysis (EDA) on the CXRs and demographic information, I trained the model on the O2 high-performance cluster. I implemented Focal Loss (gamma=3.00 and alpha=0.95) and class weightage to counteract the high-class imbalance. The optimal 2D-CNN included a Gated Activation Unit (GAU) and a Multi-Head Self-Attention (heads=8), performing with a specificity of 93.7%, a sensitivity of 75.8%, and an AUC ROC of 83.7%, showcasing the strong potential for using CXRs in contact tracing.

California Northern

Plantsol: A Novel, Low-Cost Plant Disease Detection System

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American farmers are in crisis mode. More than 67% of the U.S. agricultural labor force has been lost in the last seventy-five years, making high-skilled agricultural workers difficult to find. Concurrently, increased production pressure is being put on American agricultural systems, which play a key part in the world's corn, soybean, and wheat production – staple crops for billions around the world. As a result of this coupling, farmers must take on a larger number of tasks, one of those being the detection of plant disease. This task is tedious, but also extremely important – a fact confirmed by interviews we personally conducted with farmers and agricultural experts in California. To manage plant disease, many farmers currently rely on manual approaches. Unfortunately, these are either inefficient or damaging to the environment. While automation is an option, existing solutions are either too expensive or limited to a specific environment or crop group. In response to this, we present Plantsol: a novel system that uses deep learning to identify 42 different diseases in 14 different crops with 93% accuracy, all for less than $50. The system is centered around an autonomous robot that can navigate crop rows and detect plant disease. A web application, which syncs with the autonomous robot, and a mobile application, which provides on-device disease

detection, treatment information, and access to global agricultural news, are also included. Plantsol is a breakthrough in the field of agriculture and may help solve the $220 billion problem of plant disease.

A UV Marking and Deep Learning System for Mitigating Textile Environmental Impact

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The garment industry is one of the world's largest carbon and waste polluters. In the next decade, this industry is expected to produce 150 billion garments/year, while currently recycling ~1%. Garment landfills are growing large enough to be seen from space, while water consumption side effects threaten the environment and human health. The circular economy for textiles is hampered by two challenges – automated fabric sorting and automated tracing. Without automatic fabric identification – scalable recycling measures cannot be put into effect. Without traceability, governments cannot enforce recycling laws and incentives. We propose a solution that leverages low-cost hardware along with deep learning models to create a traceability system. We develop a fabric identification component using microscope images classified by Convolutional Neural Networks (MobileNetV2, ResNet101, ResNet50 and VCG16), and a fabric tracing component that marks fabrics with a code visible only under UV light, using YOLOv8 object detection to remain effective in the presence of unique fabric challenges such as creasing and light refraction. We present experiments using several state-of-the-art algorithms and hyper-parameter tuning. Our results show over 90% accuracy for fabric identification across 14 classes and over 0.98 mAP for fabric tracing for new fabrics and over 0.93 mAP after wash cycle. We also demonstrate a prototype robotic arm to automate the fabric marker application. Finally, we provide three datasets for future research. This solution can help create a traceability system that can be implemented worldwide for a textile circular economy.

SEL Fusion System: Multisource Digital Biometrics and Stimuli for Early ASD Screening

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1 in 36 children in the USA are impacted by autism spectrum disorder (ASD). Less than half receive early intervention and support during this essential neurodevelopmental window. The current diagnosis process is costly, lengthy, and subject to interpretation bias. The SEL Fusion System focuses on identifying objective and computable digital biometrics and designing educational stimuli to provide an accessible and effective ASD early screening system. Through a child-friendly web application utilizing webgazer.js, the SEL Fusion System uses four classes of stimuli: videos, still pictures with audio narration, picture prompted storytelling activities, and games to collect two types of digital biometrics: eye gaze and audio data. Through this child-friendly website, 1014 experiment data-sets were collected from 108 participants (ASD n=30; General Population (GP) n=78) with computer built-in webcams and microphones. The eye gaze data was converted into heat maps and trained with a VGG16 model. The audio data was processed with Mel Spectrogram feature extraction and then trained with the ECAPA-TDNN model. Through multisource biometrics data collection, processing, and model training, the SEL Fusion System achieved eye-gaze/audio accuracies of 77.6% / 88.6% and stimuli-specific accuracy of 95.5%. The biometrics data under each stimuli class was further evaluated for a wide spectrum of ASD characteristics. The SEL Fusion System is the first system to

collect multisource digital biometrics data with multiclass stimuli in non-lab environments and provide accessible early ASD screening and developmental monitoring with minimal cost and lessened stigma.

Grand Theft Transcription Factor: Reversing Tumor Cell Immortality by Transcription Factor Relocalization

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Glioblastoma (GBM) is the most predominant malignant brain cancer in adults without prognosis improvement in decades (average survival interval of 14-17 months). Nevertheless, 83% of GBM cases have mutations in the Telomerase Reverse Transcriptase promoter (*TERT*p), responsible for maintaining telomeres. *TERT*p mutations create an ETS factor binding site, enabling the ETS transcription factor, GABP, to bind and reactivate *TERT* expression. While directly targeting telomerase has systematic toxicity, targeting GABP may allow for tumor-specific *TERT* silencing. Still, targeting transcription factors with small-molecule inhibitors is nearly impossible, so a novel approach is required.

To address this, we engineered *GABPB1L* dominant negative (*B1L-DN*) transgenes by removing the transactivation (TAD-DEL) or both the TAD and the nuclear localization signal (TAD-NLS-DEL) domains. We hypothesized that with only TAD deleted, *TERT* expression would decrease, but the protein still could enter the nucleus. However, the DN with both NLS and TAD deleted would not enter the nucleus, ensuring the decrease of *TERT* expression. To test this hypothesis, we transduced GBM cells with either *B1L-DN* or an empty vector and measured *TERT* expression by RT-qPCR and protein subcellular localization with immunofluorescence staining. We observed a 70-80% decrease in *TERT* expression by cells expressing either dominant-negative. Furthermore, immunofluorescence staining showed that GABPA was bound to the TAD-NLS-DEL-DN and could not enter the nucleus, thus rendering GABPA futile. If we can deliver the modified TAD-NLS-DEL-DN with viruses specifically targeting cancer cells in a *TERT*p mutant patient, this could be a potential application to inhibit tumor growth and thereby reverse immortality.

The Creation of SPIRo: An AI Based Origami Soft Robot with Multidimensional Locomotion for Gas Leak Detection

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Co-researcher: Evan Zhang

Methane, a super pollutant thirty times more potent than carbon dioxide, is responsible for one third of the global warming caused by greenhouse gasses. With millions of tons of methane released into the atmosphere from major and fugitive gas leaks every year, there is an urgent need to develop an accurate, efficient, and cost-effective method for inspecting gas pipes. This research presents the first AI based origami-inspired soft robot with multimodal ensemble learning for real-time gas leak detection in remote, complex, and upstream pipeline environments. Our compact, lightweight, and modularized soft robot SPIRo moves at a speed of 15 mm/s through individually actuated pneumatic McKibben artificial muscle actuators, which offer increased strength and extension distance. SPIRo utilizes curved magnetic feet to attach to a variety of pipe surfaces, and it has two metal oxide gas sensors and a thermal camera, which collect data about the pipeline environment. A multimodal deep feature fusion system with the deep forest classifier is

developed for improved accuracy, redundancy, and efficiency. Thus, SPIRo achieved an accuracy of 88% in a simulated gas leak testing environment and 77% on real field data of gas sensors collected from the METEC lab at Colorado State University, demonstrating the capabilities of SPIRo's real time gas leak detection. Finally, SPIRo is being integrated with a portable air compressor and valve system to increase its range. SPIRo can also be applied to infrastructure assessments for structures such as nuclear facilities and chemical plants that are hazardous to access.

California Southern

EMBER: A Novel Quantum Computing Framework for Early Diagnosis and Predictive Biomarker Identification of Lung Cancer

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Lung cancer is the most deadly form of cancer, responsible for over 2 million deaths annually. Its fatality is largely a result of difficulty in early detection, with survival rates dropping 57% when detected late. The standard for lung cancer diagnoses has been CT scans, yet they lack efficiency and accessibility, resulting in over 75% of lung cancer cases going undetected until late stages. Recently, researchers have used Machine and Deep Learning to improve upon traditional approaches, but these computational methods still fall short due to issues such as overfitting and feature isolation.

In order to improve upon current computational approaches to lung cancer diagnosis, EMBER leverages quantum computing, effectively avoiding the limitations of traditional computational models. Using gene expression data collected from inexpensive and accessible blood tests, EMBER predicts the presence of lung cancer as well as its expected progression, allowing doctors to make rapid decisions regarding patient treatment. EMBER utilized fundamental quantum properties such as superposition and entanglement to analyze gene expression in a more biologically applicable manner. In doing so, EMBER achieved an accuracy of 93% for lung cancer diagnoses on a large, diverse patient dataset as opposed to the 85% accuracy of the baseline classical Deep Learning model. In addition, EMBER identified a novel biomarker of lung cancer in microRNA gene 4456. Overall, EMBER allows for accurate and affordable lung cancer diagnoses, substantially increasing early detection and, thus, survival rates for lung cancer patients of all backgrounds, demographics, and socioeconomic statuses.

Attention Based Tracking Head for Multiple Object Tracking in Autonomous Vehicle Perception Systems

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Autonomous vehicles have a high potential for safety benefits and are still being developed. Many perception systems in autonomous driving are equipped with cameras to develop an understanding of the driving environment. Since information about the movement of pedestrians and other cars over time is crucial for handling possible changes to the driving situation, perception systems are faced with the Multiple Object Tracking (MOT) problem. Solving the MOT problem requires temporal information from prior image frames of the driving scene to be exploited. However, the optimal method for incorporating temporal information into object detection, localization, and tracking remains unclear. In this paper, we introduce an attention-based tracking head, which incorporates temporal information exclusively into the tracker head. By employing an experimental design paradigm, we trained and evaluated our MOT model using a subset of the BDD (Berkeley Deep Drive) 100K dataset. After comparing our model performance with the QDTrack baseline MOT model through quantitative analysis, we find that our proposed model architecture design is a plausible solution to tracking. In the context of the autonomous driving literature, this distinct approach to tracking objects via an attention mechanism for the perception system clarifies the contribution of our work.

Predicting Next-Day Wildfire Spread with Environmental Data and Machine Learning

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Wildfires present a growing challenge, increasingly threatening communities and ecosystems worldwide. The rising wildfire incidents amplify environmental and social risks, emphasizing the need for innovative approaches in fire management.

Traditional fire prediction models like FSPro, BehavePlus, FARSITE, and FlamMap have limitations in handling complex wildfire behaviors. AI models, in comparison, hold the potential for enhancements in early detection, real-time support, and wildfire management.
This project uses AI to predict next-day wildfire spread. The “next-day” timeframe balances computational efficiency with actionable insights. Two machine learning models, UNET and Random Forest, were compared. Feature analysis was conducted to identify the most important features for both models.

The UNET, which could interpret spatial relationships between pixels, outperformed the Random Forest in all metrics except AUC, supporting our first hypothesis. It also outperformed the convolutional autoencoder created by the Google developers of the Next Day Wildfire Spread dataset in precision and recall, highlighting its effectiveness.

Our second hypothesis was rejected. Feature importance varied; the previous fire mask was most important for the UNET, but only third most important for the Random Forest. Additionally, the impact of feature addition differed between models, suggesting that focusing on the most informative features could be more effective than collecting all available data.

Our models were able to predict a wildfire’s next-day spread patterns, offering a potential improvement over current prediction methods. Further refinement and application could aid firefighters in allocating resources to high-risk areas, leading to more effective containment efforts, and enable authorities to make timely evacuation decisions.

Fluid Shear Stress enhances the metastatic potential of human colon cancer cells: A critical role of Nitric Oxide

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Colorectal cancer is the third most diagnosed cancer and the second leading cause of cancer-related deaths worldwide. Despite therapeutic advances to treat the primary tumor, metastasis causes greater than 90% of cancer deaths. The role of Fluid Shear Stress (FSS) on colon cancer metastasis and whether this biomechanical force imparts any biochemical changes in the circulating colon cancer cells is not well understood. In this work, a bioengineering model is used to simulate the laminar FSS experienced by cancer cells using a parallel plate flow chamber. Exposure of HCT116 (human colorectal carcinoma cells) to physiological FSS stimulated metabolic activity, proliferation and colony formation. An in-depth mechanistic analysis identified nitric oxide (NO) as a crucial mechanosensory signaling molecule that confers the pro-oncogenic and pro-metastatic signal in HCT116 cells. Pretreatment with nitric oxide synthase (NOS) inhibitor, LNAME inhibited the FSS stimulated downstream pro-metastatic signature events. A systematic concentration curve analysis using NO donor, PAPA-NONOate, indicates that NO exerts a biphasic effect in colon cancer progression. Low NO concentration (1-100 nanomolar) promotes colon neoplasms. However, at micromolar concentrations (>1 mM), NO exerts cytotoxic effects and inhibits colorectal tumorigenesis. This raises the possibility of using serum nitrate/nitrite levels as a potential biomarker to aid in the early detection of colorectal cancer metastasis. Development of efficient drug delivery systems to deliver sustained high doses of NO directly to the primary tumor site may be effective in arresting primary tumor growth and delay or prevent colon cancer metastasis.

Integrated Stress Response Activation Discovered to be Predominant Response to Mitochondrial Dysfunction: A Therapeutic Target Advancement

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Our bodies continuously face genetic and developmental stresses and use stress-responsive signaling pathways to promote proteome remodeling. However, these insults result in pathogenesis when persistent upon signaling pathway dysfunction. Additionally, the lack of selective therapeutics has led to considerable interest in defining the molecular mechanisms responsible for regulating cellular proteostasis in response to pathologic insults. As previously discovered, the Unfolded Protein Response regulates global cellular physiology in response to endoplasmic reticulum stress. Yet, the UPR is not the only response leading to pathogenesis correction; the Integrated Stress Response is another, involving selective phosphorylation of eIF2α kinases for transcription factor activation. Nonetheless, the ISR's role in etiology mitigation remains largely unknown. Post validation of our gene-set profiling approach using known UPR targets, we monitored the expression of gene-sets regulated downstream of pathways with perturb-seq datasets from K562 cells CRISPRi-depleted of mitochondrial proteostasis factors. We found the ISR predominantly activated in response to broad-scale mitochondrial disruption, and documented novel therapeutic targets: IARS2, PRELID3B, SLC25A42, TIMM23B, and TOM22. Further, mitochondrial protein processing and targeting were among the notable functions discovered of ISR target genes through Gene Ontology. Our identification of the ISR as the predominant stress-responsive signaling pathway activated by mitochondrial proteotoxic

stress underscores a unique opportunity to target the ISR to correct pathologic mitochondrial dysfunction in conditions like type 2 diabetes, the result of β-cell anomalies. Ultimately, this viable gene-set profiling approach holds promise for identifying therapeutic targets and biomarkers across the proteome, advancing progress to mitigate cancer, metabolic, and neurodegenerative disease.

Connecticut

Synthesis of Conductive Optical Lenses for the Observation of Variable Refractive Indices

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Teacher: Kirk Shadle, Bridgeport Regional Aquaculture Science and Technology Education Center

The application of electrical energy and induction of changes to refractive indices of different mediums could drastically impact the development of modern optical science. To explore the properties of these variations, two lenses of different natures have been synthesized. First, a simple 50 mm diameter glass plano-convex lens was coated in a tin oxide layer, by spraying a solution of methanol and tin(IV) chloride pentahydrate onto the surface at 600 degrees Celsius. Additionally, an acrylamide-based hydrogel was synthesized to observe the conductivity of a water-based medium. These lenses were tested using a vernier light sensor apparatus, using a green laser light of 532 nm to pass through a conductive medium. Data demonstrates dynamic linear results showing a strong inverse correlation between the voltage present in the lens, and the lux reading of the light sensor. Testing in hydrogels seemed to be dominated by an internal thermal flux, while the tin oxide coating showed results consistent with the Kerr effect. Across 24-minute trials, increasing from 0 volts to 15 in 5-volt intervals, Lens 2, yielded a correlation coefficient of -0.926, and Lens 4 yielded a correlation coefficient of -0.924, both denoting a strong relationship that describes the lens displaying a variable refractive index. Further research in this topic will open the door to more developed optical technologies, involving more dynamic refractive properties that allow for modularity in controlling the movement and position of light, impacting both the field of optics and consumer industry.

DETICKT IT: A Machine Learning-Based Application for Real-Time Tick Identification and Spatiotemporal Disease Risk Assessment

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Teacher: Victoria Schulman, King School

There is an alarming increase in the population of ticks and tick-borne diseases (TBDs), with 475,000 cases reported annually, some of which are fatal (Kugeler et al., 2021). Due to limited training, healthcare providers and the public cannot always accurately identify ticks and their associated infections, leading to delayed diagnoses and treatments. Additionally, the prevalence rates of different disease-causing pathogens vary based on geographic locations. To facilitate the identification process and provide an expedited risk assessment of TBDs, a machine learning-based iOS application, DETICKT IT, was created. The app features a ResNet50V2 deep convolutional neural network built in Python for combining real-time tick-species identification with a novel “window” algorithm and a location-based tick-risk assessment by embedding the Centers for Disease Control and Prevention’s spatiotemporal tick and pathogen surveillance statistics. With DETICKT IT, users can now receive an immediate and accurate analysis to determine

whether they are at risk of contracting certain TBDs. The app is able to accurately identify the ten most common tick species in North and South America: American dog tick, Asian Longhorned tick, Brown dog tick, Eastern blacklegged tick, Western blacklegged tick, Groundhog tick, Gulf Coast tick, Lone star tick, Rocky Mountain wood tick, and soft tick, with an overall accuracy of 97% and precision, recall, and F1 score metrics of 0.96, 0.97, and 0.96, respectively. This freely accessible app shows promise in assisting tick bite victims with their decision to seek medical assistance, particularly those with underlying health conditions.

Development and In Vitro Verification of a Polymersome for Blood-Brain Barrier Transport Through a Novel Machine Learning Model

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Teacher: Andrew Bramante, Greenwich High School

Across neurological drug development, researchers struggle with the high selectivity of the blood-brain barrier (BBB), where most drugs are unable to pass from the blood into the brain. As such, drug-treatment of Alzheimer's, Parkinson's, brain cancer, and strokes remains difficult. Recent research identified polymersomes (polymer-based vesicular shells) as an avenue for transport of otherwise non-BBB-permeable drugs across the BBB. However, the number of discovered BBB-traversing polymersomes remains low, and they are not able to carry all drugs. Recently, machine learning has emerged as a powerful tool in medicine. This research developed a machine learning model to identify likely polymer candidates for polymersomic drug-delivery across the BBB. The model was programmed in Python using TensorFlow and trained on 7,807 molecules from the B3DB-database. It achieved 93% accuracy and identified 13 encapsulation candidates. The top candidate for BBB permeability, ammonio methacrylate (AM), had never been considered for BBB permeability before. To validate the model, a polymersomic nanoparticle (AM-DOX) was developed by encapsulating doxorubicin (DOX, an anti-tumor drug) with AM, for eventual passage across an *in-vitro* BBB model (parallel artificial membrane permeability assay). 500µM-DOX and 500µM-AM-DOX were separately introduced to the BBB model for 24 hours at 37^{o}C. While DOX was predictably unable to penetrate the BBB, the AM-DOX nanoparticle successfully passed, producing an equilibrium 250µM concentration surrounding the barrier. This was validated via UV-Vis and ATR-FTIR spectroscopies, providing compelling evidence for a new, effective BBB-encapsulation polymer, identified via machine learning, to deliver treatments for a wide array of neurological disorders.

Synthesis of Porous Polymer Sponge Matrix using Modified Sodium Alginate Clay Compound for Adsorptive Removal of Microplastics and Oil from Contaminated Water

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Mentor: Ms. Alyssa Anderson, Science Teacher

Many water sources, including drinking water, contain microplastics and oil. Both contaminants are harmful to us and the environment, yet current removal methods are inefficient, expensive, and/or not environmentally-friendly. Through synthesizing a clay-alginate sponge matrix with an ionic liquid (IL), an efficient method to remove microplastic and oil contamination from water will be devised. Montmorillonite clay (MMT) is naturally-abundant, safe, and inexpensive, with notably great adsorption properties and high surface area, essential for an efficient water filtration system. My past research has confirmed pure MMT's effectiveness in removing microplastics and oil, prompting my current research for optimization. Sodium

alginate (SA) is a safe commonly-used substance that can increase the clay's adsorption affinity for pollutants due to its backbone structure with excess carboxyl and hydroxyl groups. Loading the sponge matrix with an IL further increases adsorption as well as stability, as ILs have shown promise in organic pollutant removal. The sponge matrix with the IL loaded clay-alginate compound will be synthesized using both freeze-drying and dip-coating methodologies. Research analyzing removal capabilities of MMT with SA and a loaded IL was conducted using ultraviolet-visible spectroscopy analyses, with scanning electron microscopy to investigate the matrices' surface structures. The sponge matrix with SA, MMT, and IL indeed yielded the highest results, removing 77.87% of PETE microplastics and 81.71% of gasoline oil at 20°C with a 60 min treatment period. A prototype of a standard filter with multiple compartments for a household water filtration was developed using 3D modeling software and is currently being tested for optimization.

Quantum Computing in Medical Diagnostics: A QSVM Approach to Alzheimer's Disease Classification

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The task of accurately diagnosing Alzheimer's Disease (AD) is challenging, requiring the classification of the disease into distinct stages: Non-Dementia, Very-Mild Dementia, Mild Dementia, and Moderate Dementia. Traditional machine learning (ML) classifiers such as supportvectormachines,k-nearestneighbors,decisiontrees,randomforests,andartificialneural networks are broadly effective in handling Alzheimer's Disease datasets. However, as the complexity and size of these datasets grow, these classifiers become increasingly computationally intensive, highlighting a critical need for more efficient and powerful algorithms. Parallel advancements in quantum computing and ML suggest that quantum technologies could optimize traditional MLmethods. Quantum computation has the potential to overcome the computational constraints of classical computers, allowing for more efficient processing of data. The integration of quantum machine learning represents a significant advancement as its capacity to process large and intricate datasets could substantially enhance Our understanding of biological systems and disease progression. Herein, Ipresenta Quantum Support Vector Machine (QSVM), specifically designed for AD classification given MRIs of brain images from a preprocessed AD dataset. This model aims to leverage quantum computing's strengths to handle large datasets and complex patterns in biological research more effectively. I conducted a thorough evaluation of the QSVM, comparing it to several traditional algorithms. This involved analyzing time complexity and performance metrics such as accuracy, precision, recall, and F1-score. My findings provide insights into the QSVM model's operational effectiveness and its comparative performance, offering a nuanced understanding of its applicability in medical diagnostics and the broader field of ML.

DoDEA Europe

Formulation and Testing of Properties of Starch Based Bioplastics with Cellulosic Reinforcement

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Teacher: Daniel Coapstick, Stuttgart High School

With an ever-rising plastic waste problem and increasing greenhouse gas emissions, a solution is needed to reduce the environmental impact of plastic while still benefiting from its functionality. Bioplastics, or plastics made from natural materials, have arisen to address this problem, and starch-based bioplastics are receiving special attention due to their easy manufacturability and accessibility. However, pure starch-based bioplastics are weak and require reinforcements in order to improve their mechanical properties so they can be useful for applications. Cellulose and its derivatives have been highlighted as a positive reinforcer for starch-based bioplastics, improvement in strength being one of the most highlighted benefits. This study aims to test which of the two forms of cellulose I, α or ß, provides the greatest benefit to starch-based plastics by improving its mechanical properties. This study specifically tests tensile strength and water solubility to compare three varieties of bioplastic based on these characteristics. The end result demonstrates cellulose Iα was the superior plastic when tested with water solubility and tensile strength, with beta barely providing any benefit over the control.

Increasing Machine Learning Training Data to Reduce Selection Bias in AI

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Artificial Intelligence (AI) is growing expeditiously in today’s world and being used for many different real-world applications like healthcare, law enforcement and CCTV, recruiting for companies, etc. This has led to an increase in selection bias, which results in AI developers over representing a specific group of people (usually white and western) and underrepresenting other minorities, so that many facial recognition systems and search engines don’t recognize them or recognize them too much. The purpose of this research is to replicate selection bias and a solution for it by using emotional/type three AI to recognize whether the Teachable Machine software (created by Google) the researcher trained can accurately predict emotions and accurately predict emotions for different skin complexions. The researcher used fair skin toned faces and very small data sets at first and then continued increasing the data sets used to train the model and made them more representative of other skin tones. The researcher’s hypothesis was supported by the results at the end since the correlation between skin tone, data set amounts, and result accuracy decreased, meaning that selection bias decreased as well.

Prioritization of Pneumothorax Diagnosis in Management: Automating a Severity-Based Urgency List System with Deep Learning

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Pneumothorax, known as the presence of air within the pleural space, has a reputation of demanding timely intervention. But when this abnormality is classified as a tension pneumothorax, the situation becomes life-threatening and in need of emergency care. To continue with an urgent intervention procedure, a radiologist must first interpret a radiograph of the case, and issue directions for further treatment. The absence of a standardized approach in prioritization of pneumothorax cases often results in the lack of a specific order for viewing studies, potentially delaying critical diagnoses. To solve this, a machine learning pipeline was developed with the fundamental functionality of creating segmentation masks, a severity score of a case, and an urgency-list function to enhance the process of a prioritization workflow and decrease negative effects and fatalities due to pneumothoraces. The model was trained on a dataset from the Society for Imaging Informatics in Medicine which contained 10675 annotated run length encoded pneumothorax images. Using a U-Net based model with primary EfficientNetB4 layers, semantic segmentation was achieved to highlight sections of the pleural cavity classified as pneumothorax. The model reached dice coefficient accuracy of 0.8038, pixel-wise accuracy of 0.9961, IoU of 0.9305, precision of 0.7477, recall of 0.8, and anomaly detection accuracy of 0.8120. After generating plots of images organized by their calculated severity scores through volume measurement, the pipeline exhibited accurate performance in displaying results classified as life-threatening at the top of the UrgencyList and results with no pneumothorax detected at the bottom.

The Effect of Out of Envelope CG on Model Aircraft Distance Performance

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The study and calculation of CG or center of gravity is crucial in the aerospace fields. It in short ensures that planes stay balanced in the air and are able to maintain straight and level flight. Center of Gravity calculations are the number one cause for general aviation accidents and incidents. Having a better understanding of the effects of imbalanced CG could allow for the improving of safety in general aviation and could better prepare pilots if they are in a position where their plane is imbalanced. It is clear in aviation that the more prepared you are the better the outcome. The testing was done with a launching device that ensured equal launches and angles every time. Distance was then measured and centers of gravity calculated using the standard weight, arm, moment method. The results showed that in all cases centers of gravity displaced more then 11% forward or aft result in poor distance performance and dangerous irregular flight patterns. In conclusion it was determined that balanced CG is crucial to safe flight and also the ability to fly straight and level. Overall distance performance decreased during both forward and aft displacements resulting in worse performance.

DoDEA Pacific

Potential of Seagrass as a Localized Bioremediation Agent for Ocean Acidification in Coral Reef Ecosystems

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Coral reefs are one of the most biodiverse ecosystems on the planet. Burning of fossil fuels pollutes the atmosphere with increased carbon dioxide (CO_2) which leads to ocean acidification (OA). This is detrimental to coral health and can cause bleaching and reef damage. Introducing photosynthetic organisms such as seagrass near coral reefs might mitigate the effects of OA and reduce the excess CO_2 locally, protecting the coral ecosystem. It was hypothesized that seagrass exposed to raised CO_2 concentrations could remove it through photosynthesis, but would have a limit in tolerance to acidity and capacity to influence CO_2 concentration. The seagrass *Zostera Marina*, in aquarium tanks, was challenged over 4 days during daylight, to increasing concentrations of CO_2 in salt water. The response was studied with controls for CO_2 surface loss, and photosynthesis without additional CO2. The pH values were recorded pre-dawn, and at 30 minute intervals after the addition of carbonated water. The impact of photosynthesis on increased CO_2 levels was measured indirectly through changes in the pH. When adjusted for surface CO_2 loss, pH recovered to baseline with a rate of pH change of 0.042-0.12 per hour. At maximum response, the pH change in the seagrass rank compared to pH in the control tank was statistically significant with $t(40) = 6.306$, $p > 0.00000018$ These results suggest that seagrass is a viable buffer for rises in ocean CO_2/H_2CO_3 and if co-planted with coral could mitigate the effects of OA protecting coral from damage.

Comparing the Eddy Current Generation Between North-South Array and Halbach Array for Magnetic Induction Heating Element

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This project aims to use an eddy current generator using a Halbach array to create a sustainable heating element for water desalination and test the effectiveness of a north-south array versus a Halbach array. A Halbach array having nearly double the magnetic field on one side of the array will allow the eddy current generator to heat the copper plate to a higher temperature faster than the north-south array. Temperatures were measured every minute for 15 minutes on the copper plate exposed to eddy currents from the rotating north-south array and the Halbach array. At 10V input, the copper plate in the north-south array increased from a temperature of 24.78℃ to a final temperature of 39.11℃ while in the Halbach array increased from 24.61℃ to 94℃. At 15V input, the copper plate in the north-south array increased from a temperature of increased from a temperature of 25.28℃ to a temperature of 60.72℃, while in the Halbach array, it increased from 24.89℃ to a high temperature of 115.89℃. In conclusion, the hypothesis was proven correct as the Halbach array, having nearly double the magnetic field on one side of the array, allowed the eddy currents generated in the copper plate to increase the copper plate to a higher temperature and at a faster rate than the north-south array. The higher temperature and faster rate mean that the Halbach array does provide more efficient heating of nonferromagnetic thermal conductive materials than a north-south array.

Caffeine’s Role in the Phytotoxicity of Spent Coffee Grounds

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8 to 15 million tons of spent coffee grounds (SCG), the remainder left after brewing coffee grounds, is produced every year globally. To reduce waste in landfills, SCG has been proposed as an agricultural soil amendment due to its high organic content of carbon and nitrogen. However, raw SCG also has phytotoxic properties when added to soil, which has been largely contributed to its phenol compound and caffeine content. This study seeks to isolate the effects of caffeine within SCG to determine whether or not caffeine has an inhibitory or enriching effect on plant growth. It was hypothesized that decaffeinated SCG would have less of an inhibitory effect on plant growth in comparison to caffeinated SCG when administered as a soil amendment. Three treatment groups were created within the design of the experiment (Control, Caffeinated, and Decaffeinated). 3.5% (w/w) of caffeinated and decaffeinated SCG was administered to the agricultural soil before planting *Lactuca sativa* seeds. The control group had no SCG administered. Both the caffeinated and decaffeinated SCG were treated via the conventional solvent extraction method to reduce the inhibitory effect of phenol compounds. The control group significantly outperformed both other treatment groups. However, when comparing the caffeinated and decaffeinated groups, the larger mean biomass of the caffeinated group would suggest that the caffeine within SCG promoted plant growth. These results are in direct contrast to the hypothesis and previous ideas regarding caffeine as a phytotoxic compound within SCG.

Prochlorococcus-Mediated Restoration of Hypoxic Ecosystems Across Varying Levels of Turbidity in Aquatic Environments

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The current approaches to manage hypoxia caused by high turbidity levels only prevent or lessen the quantity of sediment discharge; little research is done on the areas that are already hypoxic, which causes these areas to become low-nutrient because aquatic plants' opportunity to photosynthesis is reduced. The goal of this study is to utilize the Cyanobacteria *Prochlorococcus marinus* to provide a bioremediation solution to locations where sediment flow has caused hypoxia. When exposed to high turbidity conditions, *Prochlorococcus marinus* will create an equivalent or comparable amount of oxygen to when it is not present in low turbidity conditions. In order to simulate aquatic habitats, fifteen tanks were set up with varied turbidity levels and the common aquatic plant *Phaeophyceae* (brown algae). Turbidity levels were shown using the inhibition of different amounts of UV light (25%, 50%, 75%). Analysis through an When and ANOVA statistical test was performed, the results indicated that there was a significant effect of time (p-value day < 0.0001) and the presence of *Prochlorococcus marinus* (p-value treatment < 0.0001) on oxygen production levels. Ultimately supporting the hypothesis that when *Prochlorococcus marinus* is exposed to high levels of turbidity-mimicked conditions via UV light inhibition, it does affect ecosystems by producing equal or similar levels of oxygen. With this in mind future research should focus on applying *Prochlorococcus marinus* to actual marine ecosystems that currently face hypoxia to replicate the results of the current study.

Analysis of Traditional Korean Herbal Remedies Hwangryunhaedok-tang and Gamroeum for the Mitigation of Type 2 Diabetes with *Drosophila Melanogaster*

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Type 2 Diabetes (T2D), a progressive chronic disease of the endocrine system, is among the most commonly diagnosed disorders today. Due to the limitations of current treatments, this work explores therapeutic interventions for T2D with alternative medicine, drawing insights from Traditional Korean Medicine (TKM) practices. While research in TKM is continuously expanding, particularly in the sphere of T2D, previous research is often limited in its assays and high variability. Thus, to contribute to the growing necessity of novel treatments and validation, this study employs an *in vivo* analysis of T2D with the model organism *Drosophila melanogaster* to investigate two herbal prescriptions, Hwangryunhaedok-tang (HRHDT) and Gamroeum (GRO). Reviewing the literature, there is an increasing popularity of *Drosophila melanogaster* as a model for pharmaceutical assays due to its unique ability to mirror the complexities of human disease and composition — especially in endocrine disorders — as well as its relatively affordable maintenance and availability of tools. Employing the widely accepted high-sugar diet to induce T2D and insulin resistance in *Drosophila,* the remedies were analyzed on indices of survival, pupa development, fertility, negative geotaxis scales, and body length. Based on these assays, HRHDT significantly improved the high-sugar induced abnormalities by increasing lifespan, individual size, and fertility. GRO also increased survival and fertility to a lesser degree. Providing *in vivo* evidence of the clinical viability and benefits of HRHDT for the mitigation of T2D, the present study ultimately supports the role of the herbal mixtures in improving the adverse effects of insulin resistance.

Florida

In Pursuit of New Soil-based Bacteriophages that infect *Gordonia rubripertincta*: Discovering *Evergreen*

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One option to mitigate antibiotic resistance is bacteriophage therapy. Phages, a type of virus, are genetically diverse and globally plentiful. Yet, few have been discovered. This two-phase study isolated, sequenced and annotated a phage that infects *Gordonia rubripertincta,* an opportunistic bacterium. Evergreen22 was discovered after a lengthy procedure of isolation, purification, amplification, and DNA extraction.

Another novel phage—KayGee—, was auto-annotated using DNA Master, which indicated 73 genes. Following the 14-guiding principles recommended by Turner and colleagues (2021), each of the 73 genes for KayGee was manually refined using an additional 8 bioinformatic tools. The annotation also revealed that KayGee has two rare genes only seen in one other CT-cluster phage called Pons, adding to the phage taxonomy knowledge-base. The annotation was sent to PhagesDB for addition to the metagenomic database.

All three hypotheses were supported. A second wet-lab temperature study showed the optimal infection temperature of Evergreen22 to be 35°C, implying it would be efficacious in humans (body temperature is 37°C). The study compared Evergreen22 and KayGee on plaque morphology, annotations and the

temperature study, and showed the phages to be lytic phages that do not produce toxins. By using the genomic and biosynthetic components of the host bacteria, lytic phages multiply rapidly and cause the bacteria to lyse. Both phages are suitable for phage therapy. Furthermore, both phages can be used in bioremediation, therapeutic phage cocktails, and food preservation. Future studies should conduct one-step growth curves for both phages to determine the burst size of each.

Discovery of a Polymorphic Biomarker More Accurately Associated with Reduced Chemotherapeutic Metabolism in a Diverse Cohort

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UGT1A1 is an enzyme involved in metabolizing Irinotecan, a DNA topoisomerase class I inhibitor chemotherapeutic drug. Polymorphisms within the UGT1A1 gene promoter reduce UGT1A1 mRNA expression, rendering individuals susceptible to heightened drug toxicity. Irinotecan toxicity makes it crucial to identify the polymorphisms responsible for reduced mRNA expression and then use the polymorphism as a biomarker for personalized therapy. Previous research studied only Caucasian individuals and determined that a polymorphism within the UGT1A1 gene promoter's TATA box was responsible for reduced mRNA expression. Although this polymorphism has been used to guide Irinotecan prescriptions, it is loosely associated with reduced mRNA expression in other populations. Comparing mortality rates between Caucasians and African Americans prescribed Irinotecan based on the presence of the TATA box polymorphism, reveals higher mortality rates among African Americans. Therefore, this research expands its scope to encompass both African-American and Caucasian populations. This study investigates a nearby single nucleotide polymorphism (SNP), rs887829, located within 300 base pairs of and in linkage disequilibrium with the TATA box. Liver samples were collected from both groups, with subsequent extraction of gDNA and total RNA. The UGT1A1 gene promoter region was amplified, and fragment analysis was conducted to genotype UGT1A1 gene promoter TATA repeats. The rs887829 polymorphism was genotyped using Illumina SNP Array, and UGT1A1 mRNA expression was quantified using real-time PCR. A linear regression model was used, which determined that the rs887829 SNP is a more accurate biomarker for reduced UGT1A1 mRNA expression, which better serves all ethnic groups.

3D Printing Personalized Knee Implants: Novel Computational Geometric Models for Stem Cell Regeneration in Meniscus Tears

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The most common knee injury is a torn meniscus, affecting 65% of all adults and contact-sports athletes. The meniscus is the primary cartilage in the knee, stabilizing over 85% of the total loads. Currently, commercially available meniscus implants are not personalized or representative of the physiological properties of the meniscus, resulting in poor tissue regeneration and the onset of osteoarthritis. This investigation 3D-printed novel composite implants by combining polycaprolactone scaffolds and gelatin/chondroitin sulfate hydrogels. The implants were personalized using patient-specific tear MRIs and latticed using computational geometry. Finite element simulations were used to optimize lattice structure under physiologically relevant knee conditions. The resulting implant models were structurally and biologically characterized in comparison to the positive control, porcine meniscus tissue. The implants were able to absorb 93 times their dry weight and match the 70-75% water composition of porcine menisci. Scanning electron micrographs and micro-CT scans showed an open pore geometry with an average size of 215 μm with localized differences, conducive to cartilage repair. Rheological frequency sweeps found a complex modulus, an indication of stiffness and elasticity, of 132 megapascals. All structural properties mimicked porcine tissue, as indicated by statistically insignificant results. The implants supported the chondrogenic differentiation of ligament stem cells, as was confirmed through cell staining. MTT assay

found 10-fold cell proliferation from initial seeding with >97% viability. Overall, the novel implant developed in this project is a viable regeneration option, important in the context of sports medicine and the prevention of osteoarthritis.

The Investigation of the Therapeutic Effects of High Nitrate Concentration Beetroot Juice on the Pathophysiological Progression of Duchenne Muscular Dystrophy with Drosophila Model

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The purpose of this study was to investigate the potential therapeutic effects of high nitrate concentration beetroot juice on the pathophysiological progression of Duchenne Muscular Dystrophy, utilizing a *Drosophila melanogaster* model. Four diets, with different concentrations of beetroot juice (0%, 10%, 25%, 50%), were prepared and administered to dystrophic flies (Bloomington #25210) and wild type flies (Carolina Stocks #172100). Muscle function was assessed using a negative geotaxis assay, which recorded the percentage of flies to reach 8 centimeters in 12 seconds, and with the Drosophila Activity Monitor which measured the number of times individual flies crossed the center of a small tube. Nitrite levels, an indirect measurement of nitric oxide, were assessed with a nitric oxide assay kit. Data from this study indicates that walking frequency increased in the dystrophic flies fed 10%, 25%, and 50% beetroot juice diets, while climbing ability improved in those fed 25% and 50% beetroot juice diets. Nitric oxide levels significantly increased in the dystrophic flies fed a 50% beetroot juice diet. Beetroot juice improved muscle function and reversed the effects of Duchenne Muscular Dystrophy in *Drosophila*. Beetroot juice also restored the nitric oxide levels in the dystrophic flies, suggesting increased vasodilation and mitochondrial efficiency. This study suggests that patients with Duchenne Muscular Dystrophy may benefit from a diet rich in beetroot juice. This study may have implications on future pharmaceutical and nutraceutical product development which may be able to combat this currently incurable disease.

The Spectral Signature of the Coherent Electronic Excitation of Ethylene

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Electronic motion governs all chemical transformations. For example, when a short light pulse excites a molecule, it creates a charge fluctuation that migrates at a speed close to 500,000 mph, impacting molecular reactivity. Observing and controlling this ultrafast motion is extremely challenging. Only the birth of attosecond science (Physics Nobel Prize 2023) could finally open a window on the time-resolved study of electron dynamics at its natural attosecond time scale (1 as = 10-18s).

In this work, we investigate two methods to observe this motion in ethylene. First, charge migration results in an oscillating electric dipole that radiates like an antenna and can be detected with optical interferometric schemes. Second, a probe pulse is used to eject a photoelectron, whose direction reflects where the charge is instantaneously localized in the molecule. Theory is needed to interpret these complex experiments. Here, we employ ASTRA, a molecular ionization code, that can simulate the electronic motion in the presence of light pulses.

In the optical scheme, a first pulse induces a coherent excitation of two lowest states of ethylene, while a second pulse probes this coherence by promoting third-harmonic emission from either of the two states, giving rise to an observable interference. The same coherent motion is also studied by photo-ionizing the excited molecule, monitoring how the photoemission direction changes with time.

These findings open new ways to control charge-transfer processes in unsaturated molecules, with potential applications to quantum computing and communication, and in photoreceptors, with application in light-harvesting technology.

Georgia

Comparative Study of Fruit Peel Biopolymer-based Composite Films

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As single-use plastic pollution rises, bioplastic from renewable biopolymers offers a sustainable alternative; however, challenges persist in improving their mechanical properties. This study examines fruit peel powder from major plastic-polluting countries (China, India, Indonesia, Brazil, and the United States) to reinforce starch-based and agar-based biocomposite films and assess the impact on its mechanical properties (tensile strength, yield strength, modulus of elasticity, % elongation). The research introduces novel agar and starch matrices derived from fruit peel waste powder and reinforced with the same fruit waste material to prove that irrespective of the matrix type (starch or agar), increasing fruit peel powder grams (0 g. 2.5 g, 3.5 g, 4.5 g from pomegranate, oranges, apples, bananas, honeydew, cantaloupe, and pineapple) increases tensile strength, yield strength, and modulus of elasticity. To form uniform films, starch or agar powder was combined with vinegar, glycerol, and fruit peel powder. Testing with a universal testing machine showed banana peel powder exhibiting high tensile (0.04756 MPa) and yield strength (0.02924 MPa) at high peel powder concentrations due to effective adhesion within an agar matrix. ANOVA analysis indicated significant differences ($p < 0.05$) in fruit type on all mechanical properties and confirmed that increasing fruit peel powder grams improved yield and tensile strength, regardless of the matrix used. Although starch-based films exhibited lower overall strengths than agar-based films, their applications include cost-effective manufacturing and packaging. Future studies should explore degradation, chemical stability, and antibacterial properties for potential food packaging.

Early Detection of Triple Negative Breast Cancer using Multi-Functional Magneto-Fluorescent Carbon Dots

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To combat rising mortality due to cancer, it is necessary to develop early diagnostic techniques for the rapid identification of cancer before metastasis. Triple negative breast cancer (TNBC) makes up 10-15% of breast cancers and is estrogen receptor-negative, progesterone receptor-negative, and HER-2-growth-receptor negative. This lack of receptors leads to late detection of TNBC, resulting in higher death rates. Exosomes are extracellular vesicles found abundantly in the blood, containing biomarkers specific to the cell they originated from. If the presence of exosomes of TNBC could be detected in the blood, then TNBC could be detected early, thus reducing cancer mortality. This study reports the design of magneto-fluorescence carbon dot nanoarchitectures for the identification of the CD-9 exosome of Triple Negative Breast cancer. Red, yellow, and blue carbon dots were prepared using the hydrothermal method. The three carbon dots showed good fluorescence (quantum yield > 8%) and were combined with amine functionalized Fe_2O_3 magnetic nanoparticles (MNPs) using the EDC/NHS coupling method. The carbon dots (CDs) and Fe_2O_3 MNPs were characterized with various microscopic and spectroscopic techniques, including TEM, SEM, DLS, FTIR, XPS, EDX and zeta potential measurement. The MNP-carbon dot composites were conjugated with the CD-9 aptamer to form magneto-fluorescent nanoprobes. The nanoarchitectures were employed in

exosome solution and displayed good selectivity, highlighting their application as a low-cost, less invasive test to detect TNBC early.

Behavioral, Pathogenetic, and Therapeutic Modalities of Fragile X Syndrome Genetic Epilepsies

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Fragile X Syndrome (FXS) is the most common “single-gene” cause of intellectual disability (ID) and autism spectrum disorder (ASD) worldwide, often manifesting understudied seizure comorbidities in early childhood development. Herein, the *Drosophila* orthologs of five previously unstudied candidate genes (*GK5, RGPD4, CHD2, KCNA1, and TTLL4*) were functionally characterized *in vivo* to i) interpret the pathogenetic consequences of the loss-of-function (LOF) of target genes, ii) elucidate sex differences in seizure risk modification, and iii) assess the interaction of genetic risk loci and existing FXS treatment compounds for novel targeted therapeutic development.

Utilizing fly strains containing RNAi-mediated KD of rigorously-identified *Drosophila* orthologs of target genes, genetic mating schemes using the elav GAL4-UAS system were implemented for all 10 crosses to enable pan-neuronal expression of target knockdown constructs to faithfully recapitulate FXS pathophysiology. Over 2,500 adult flies underwent a 10-second vortex to stimulate mechanical shock and induced seizure conditions; immediate response to external stimulus was assessed.

In females, KCNA1 LOF was shown to significantly exacerbate seizure risk ($p < 0.05$). Conversely, in males, GK5 LOF was shown to significantly attenuate seizure risk ($p < 0.05$). Additionally, RGPD4 LOF was shown to elicit significantly different seizure frequencies in male and female flies ($p < 0.05$). Utilizing *in silico* molecular docking, 3 robust alternative treatment modalities that target the elucidated seizure suppressor/enhancer genes were identified to replace current clinical management techniques aimed merely at symptomatic alleviation and patient presentation, serving as a prominent basis for pharmacological intervention.

An Observation of Granular Locomotion with Bipedal Systems

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Survey robots have become ever prominent in exploring extreme environments; however, limitations arise as they come across unpredictable granular terrains. Current literature examines granular intrusion forces; however, drag forces have yet to be studied. To address this issue, geometric intruders, similar to cleats, were intruded and dragged through a fluidized testing bed filled with poppy seeds to see if at least one variable had a significant impact in optimizing granular locomotion by reducing terrain disruption and granular forces. The variables tested were multi-body intruders with spacings of 1, 3, 5 centimeters (cm), time delays between intrusion and drag movements of 1, 3, 4, 30 seconds (s), and intruder materials of acrylonitrile butadiene styrene (ABS) and aluminum. All variable permutations had three trials, and the maximum intrusion and drag forces were recorded in Newtons (N). Results showed that ABS was preferred for reducing forces over aluminum in all scenarios, a 1-second delay was preferred for drag but a 4-second

delay for intrusion, 5 cm spacings were preferred during intrusion, and 1 cm spacings during drag. All the variables tested had p-values of <0.001, suggesting all variables made statistically significant contributions to optimizing granular locomotion. During drag experimentation, hysteresis was observed as the first segment of the multi-body intruders left behind disturbed terrain for the second half to interact with, increasing the exerted forces. This suggests that smaller spacing intruders are ideal for drag movements as they reduce granular disruptions that could limit the applicability of previously developed predictive force models.

Low-Cost, Adjustable, Pediatric Prosthetic Leg

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The loss of a limb severely diminishes an individual's ability to function independently, hindering participation in society. The majority of amputees in developing nations encounter major constraints in obtaining a prosthesis due to the limited access to prosthetic care and lack of funds. Children face more challenges because they require frequent replacements of their devices due to growth, resulting in greater overall healthcare costs. The absence of or interruption in the use of a prosthetic leg can have detrimental effects on skeletal and muscular development.

The aim of this study was to design a low-cost, modular, and adjustable transtibial (below-the-knee) pediatric leg which would be self-adjustable in height and in volume, ideally allowing the user to retain the same prosthesis for up to four years and substitute individual components in the event a section becomes worn or damaged, thereby reducing the frequency of medical visits and costs.

This second-year project focuses on re-designing the first-year model with different methods and materials including (i) smaller increments of height adjustment to reduce limb length disparity, (ii) a volume adjustment feature in the socket to accommodate growth of the residual limb, (iii) increased strength of the pylon and locking mechanism, (iv) increased strength of the foot and enhancing its ability to reserve energy, and (v) improved comfort in the socket area. The goals to incorporate these new features while providing a natural fit and maintaining affordability were met. The prototype, costing approximately $100 and weighing 1.5 pounds, satisfied safety standards under mechanical testing.

Great Plains

Microplastic Floatation: A Novel Method to Analyze and Remove Microplastics

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Microplastics are a growing environmental crisis, microplastic pollution was initially identified in 2004 as an issue that originated in the 1960's. Microplastics are defined as plastics that are five millimeters or less in size. I created a method to optimize quantification of microplastics in sand. In addition, I created a technique to effectively remove microplastics from sand. Through the use of Nile Red staining and ImageJ, I was able

to quantify microplastics from various locations. My analysis of five independent samples from two locations revealed several key findings, including the observation that sand from Galveston, Texas contained the highest amount of contamination with an average of 415 microplastic per 5 grams of sand. In contrast, the location with the lowest particles per gram of sand was in Asbury Park, New Jersey with an average of 226 microplastics per 5 grams was observed. I removed microplastics from sand and had a removal percentage of 71% for Asbury Park and 98% for Galveston. This data reveals that all sand samples have microplastic contamination and I am able to remove microplastics. Overall, this study demonstrates the importance of using beach sand as a measure of microplastic contamination from regions that have previously remained unstudied.

Sex Differentiation in the Bile Acid Pathway

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Bile acid (BA) sequestering drugs, usually prescribed to lower cholesterol, have been shown to reduce liver triglycerides in mouse models highlighting a possible pharmaceutical treatment for non-alcoholic fatty liver disease (NAFLD), an increasingly prevalent condition in which >5% of the liver weight is comprised of lipid stores. This is crucial as current NAFLD treatment recommendations are limited to diet and exercise, with no pharmaceutical interventions available. Instances of NAFLD are increasing worldwide with 30% of the population affected. Critical to this study, there are significant sex differences in NAFLD prevalence with females experiencing a lowered risk of NAFLD until menopause when estrogen signaling is lost, highlighting the protective effects of estrogen. Estrogens enact transcriptional effects through receptors. Estrogen receptor alpha (ERɑ) is the primary estrogen receptor in the liver. Investigating the role that ERɑ plays in NAFLD manifestation, and the significance of the BA pathway in liver health could lead to new treatment developments. Our data reveals several significant sex differences in the BA pathway in response to BA-sequestering drugs. BA sequestrants increased transcription of ERɑ in wild-type (WT) female mice uncovering a possible female protective mechanism to metabolic stress. BA sequestrants increased fecal BA concentration in only female mice and fecal calories in only male mice, displaying dimorphic responses to the drug. Additionally, ERɑ does not play a critical role in the regulation of Cyp7a1, fecal bile acid concentration, or fecal energy loss.

Cell-Fie: A Machine Learning Tool to Improve the Accuracy of Fine-Needle Aspiration Biopsies in Diagnosing Breast Cancer

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Breast cancer remains a leading cause of female mortality, claiming over 42,000 lives annually. Breast cancer is typically diagnosed using core-needle biopsies with very high accuracies; however, these procedures are very invasive, painful, and costly. An alternative, minimally invasive, and more affordable diagnosis method is called a Fine-Needle Aspiration Biopsy (FNAB), however, its accuracy is only 77.5%.

This study aimed to improve FNAB breast cancer diagnoses by i) determining the significance of differences in 9 cell features of breast masses between cancerous and non-cancerous patients, and ii) use this

information to identify the optimal machine learning model for breast cancer diagnosis based on these cell features. Analyzing data from 683 patients, differences in cell feature levels were evaluated using violin plots and Welch's t-tests. Then, 5 machine learning models (logistic regression, decision tree, random forest, SVM linear, and SVM polynomial) were trained and compared using diagnosis accuracy, ROC curves, and AUC.

The results showed that the cell features of clump thickness, uniformity of cell size, uniformity of cell shape, marginal adhesion, single epithelial cell size, bare nuclei, bland chromatin, normal nucleoli, and mitosis levels are significantly higher in breast cancer patients. When these cell features were used to predict breast cancer using machine learning, the random forest model had the highest diagnosis accuracy (99.26%) and AUC (99.8%). This random forest model can be a key tool in diagnosing breast cancer earlier, less invasively, cheaply, and very accurately, potentially leading to earlier treatment and improved breast cancer survival.

Ginger Root Bioactive Compounds Specifically Inhibits Growth of Colon Cancer Cells in Culture

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Colon cancer is affluent and greatly impacts the lives of many. Ginger is a common food, yet its health benefits as a whole food and 6-gingerol, as one of its bioactive compounds in prevention of colon cancer, have not been fully addressed. This experiment investigated the effects of ginger juice and 6-gingerol on colon cancer cell growth and death. Fresh ginger roots were homogenized for juice preparation. Colon cancer SW480 cells and normal colon epithelial cells CCD-18Co were treated with ginger juice and/or 6-gingerol. Cell metabolic activity, cell apoptosis, and cell cycle arrest were accessed. Data were analyzed by two-way ANOVA with a Tukey post-hoc test and statistical significance was set at $p < 0.05$. The results showed that ginger juice selectively inhibited SW480 cell growth at 25 µL/mL for 40 hrs. 6-gingerol specifically inhibited SW480 cell growth at 0.5 µmoL/L ($p < 0.01$). More than 1 µmoL/L 6-gingerol did not give more power to inhibit SW480 cell growth. CCD-18Co cell growth rates were not changed after 6-gingerol treatments. Immunoblotting results revealed that the elevation of Myt1 levels and decreases in CDK1, p21 Wafl/Cip1 and pSer642-Wee1 only occurred in SW480 but not CCD-18Co cells. Taken together, 6-gingerol can specifically inhibit SW480 cancer cells without killing normal CCd-18Co cells through cell cycle arrest. Ginger juice can selectively inhibit colon cancer cell growth.

The Effects of Transforming Growth Factor Beta in Neuronal Innervation in Pancreatitis

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Chronic pancreatitis is characterized by the destruction of the exocrine parenchyma and progressive fibrosis. TGF-beta is a cytokine that has many important functions within the pancreas, including fibrosis and acinar to ductal metaplasia which plays a large role in the development of fibrotic tissue. Not only does TGF-beta affect the accumulation of fibroblasts and pancreatic stellate cells, but it also upregulates pancreatic sensory neurons in chronic pancreatitis–leading to increased pain. Increased sensory neuronal innervation can also contribute to PDAC tumorigenesis and perineural invasion, as bi-directional communication between sensory neurons has been shown to promote tumor formation and metastasis. This leads to the following questions: what is the role of TGF-beta in neurotrophic growth in chronic pancreatitis, and how can it affect the formation and growth of pancreatic ductal adenocarcinoma (PDAC).? By disrupting TGF-beta signaling in acinar cells, we can observe how the pancreatic micro-environment changes using immunofluorescence to visualize and quantify the amount of neuronal innervation. I hypothesized that by knocking out the TGF-beta signaling pathway, the level of nerve innervation will decrease. Preliminary results demonstrate that while there is a difference between the control and TGF-beta knockout mice, due to the heterogeneous nature of the inflammation in the pancreas it is difficult to quantify the changes in the nerve morphology without bias. With the knowledge of how exocrine-derived TGF-beta signaling affects neuronal innervation and inflammation, we can better understand neuropathy in pancreatitis and how it can lead to pancreatic cancer.

Greater Washington, D.C.

Neuroassist: Cortex-Inspired Meta-Adaptive Synaptic Framework- Revolutionizing AI in Brain-Computer Symbiosis

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Current electroencephalogram (EEG) systems suffer from low signal-to-noise ratios and poor spatial resolution, leading to inaccurate diagnosis of neuromuscular degenerative diseases. Moreover, traditional EEG analysis methods struggle to adapt to the heterogeneous nature of these disorders, resulting in suboptimal treatment strategies. To address these limitations, I introduce NeuroAssist, a groundbreaking framework that seamlessly integrates adaptive artificial intelligence (AI) with advanced neural decoding techniques to revolutionize the interpretation of EEG signals in brain-computer interfaces (BCIs). Central to NeuroAssist is an innovative actor-critic deep reinforcement learning (RL) model, coupled with integral probability metric (IPM) and double sampling (DS) uncertainty sets, which robustly decodes user intentions and provides personalized assistance. The IPM uncertainty set leverages the geometry of the state space to make the robust Bellman operator tractable, while the DS uncertainty set enables unbiased estimation of the robust Bellman operator using only nominal EEG data, surpassing the limitations of existing approaches such as the Wasserstein metric and f-divergence uncertainty sets. To capture the complex dynamics of neuromuscular degeneration, NeuroAssist incorporates biologically-inspired spiking neural networks (SNNs) that emulate neural plasticity and adaptation. This approach allows the system to dynamically adjust its connection strengths based on users' evolving EEG patterns, promoting continual adaptation to the progression of neuromuscular disorders. Notably, the SNNs in NeuroAssist exhibit a remarkable similarity to inhibitory circuits in the brain, starting unorganized but self-organizing into suppressive and facilitative clusters, developing strong self-regulatory connections, and demonstrating high levels of efficiency, parallel processing, and cognitive integration.

Minimizing In-Vitro Fertilization Failures by Utilizing Artificial Intelligence to Evaluate the Health of Human Embryos

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The quality of the transferred embryo is the crucial factor that impacts the success of the in-vitro fertilization (IVF) treatment cycle. Embryologists and other related experts in the field are responsible for deciding which embryo should be chosen to continue in the IVF process. These clinicians are faced with a life-changing task that could potentially lead to failure of conception, and they definitely should ensure their final diagnoses are accurate. Alternative tools used to make this paramount decision are limited, subjective, time-consuming, and extremely expensive. However, an embryologist's skills, coupled with the precision and accuracy of an automated evaluation system, could improve IVF success rates by ensuring consistent results. Employing modern technologies, such as artificial intelligence (AI), is the deciding factor between providing accurate or inaccurate results. This project, LetoHealth, utilizes prevalent convolutional neural network (CNN) architectures to distinguish embryo health and quality at 113 hours post insemination (hpi) on day 5 of culturation based on its morphology. In this study, I assessed ResNET-50, Xception, and custom-built multi-layered CNN architectures; Xception performed the best with a validation accuracy of 0.98, precision of 0.98, and a loss of 0.05 among these. In addition, LetoHealth includes a web-based evaluation tool built using the best-performed Xception model hosted on the cloud that embryologists and clinicians can access, producing instant results of embryo health.

FRISTS: A Novel AI Framework for Interpretable Heart Failure Prediction Through AI Feature Selection and Time Series Recurrent Neural Networks

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Heart disease is the leading cause of death in the United States since 1921. As heart failure (HF) is incurable and lethal, developing prediction models is crucial for prevention and early intervention. Current research struggles with two key challenges: (1) lackluster accuracy and precision when tested on real-world health records and (2) uninterpretable characteristics that confuse healthcare practitioners and prevent widespread adoption. To address these challenges, I introduce FRISTS (Feature Ranked Interpretable Sequential Time Series), a novel prediction approach that achieves both high performance on real-world data and transparency in its decision-making. FRISTS leverages a new combination of sequential times series-based recurrent neural networks (RNN), e.g. long short-term memory (LSTM) networks, and AI-guided feature selection. Rigorous real-world testing demonstrates that FRISTS surpasses state-of-the-art baselines, outperforming the highest-accuracy (XGBoost, LSTMs) machine learning techniques in the literature. When evaluated on nearly 18 million electronic health records (EHR) in the Cerner Health Facts database, FRISTS yields an average F1 score of 0.805 and receiver operating characteristic area under the curve (ROC AUC) value of 0.990, a four-fold increase in performance compared to baselines. A SHAP-inspired (Shapley Additive Explanations) permutation method enables interpretable feature ranking, giving healthcare practitioners insight into the model's decision-making and demonstrating that FRISTS captures more HF-related features than other interpretable models (Random Forest, Logistic Regression, and Decision Trees). Since FRISTS is extendable to any prediction task on health records, it accelerates the

adoption of machine learning methods that achieve both real-world accuracy and interpretability for AI-assisted healthcare and disease prevention.

SpecuSafe: A Non-invasive and Intelligent Approach to Cervical Examinations

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Cervical cancer, a leading cause of death in low- and middle-class areas, can be identified using visual inspection with acetic acid, but such speculum-based inspections can be subjective in areas without medical proficiency and a triggering process for women with a history of sexual abuse. The goal was to develop a diagnosis method to aid health professionals in low-access areas by designing an advanced prototype speculum and website with an integrated high-accuracy image-classification model. This computer-based project utilized a requested dataset of cervix images from the World Health Organization International Agency for Research on Cancer (WHO IARC) labeled with cancer status and characteristics and was used to train a supervised image classification model. The images were processed by image segmentation and masks to reduce the influence of specular reflection. The data was then augmented to diversify the data and improve prediction abilities, then run through the model which is integrated into an instructive website. SpecuSafe is a novel model speculum with integrated technologies to ease self-speculum-insertion, pH testing, lighting, and imaging. It is rechargeable with a resin-finish and smaller length/radius for comfort. The machine learning model functions with a high validation accuracy of 83%. The SpecuSafe speculum and website can save lives by detecting cervical cancer early in vulnerable populations, potentially improving with future steps of expanding the dataset and directly feeding an endoscopic camera's output to the model.

Bioinspired Flapping-Fin Unmanned Underwater Vehicles: Novel Deep Learning Inverse Control Methods to Optimize Efficiency, Propulsion, and Navigation Objectives on Live Constrained Autonomous Systems

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Current approaches in autonomous robotics and control engineering lack practical efficiency optimization by prioritizing propulsion or relying on simulated data. Additionally, computationally expensive and slow deep learning approaches that could optimize robotic systems can't fit constraints on live movement-by-movement control systems, which instead use preprogrammed movements or search a limited space of movements.

I introduce a novel low-cost and flexible deep learning approach to control movement-by-movement objective optimization and integrate it fully on an PID-based unmanned underwater vehicle. Sensor data I collect trains forward neural networks that use the characteristic of a movement to predict the resultant propulsion and power consumption. Various models are tuned and benchmarked for computational/time performance on a Raspberry Pi and have a mean-squared error of 0.08%.

An inverse search method invokes the forward model hundreds of times every half-second to search for an optimal movement by minimizing the created loss function, constantly repeating as the algorithm searches

for a new movement based on the requested outcome by the controller. Communication is established between the Pi and PID systems, allowing physical testing to reveal a thrust propulsion improvement of 29% and reduction in power consumption by 66% with comparable performance insights with other AV platforms through a dimensionless figure of merit.

This expands the envelope of possible UUV missions including defense, climate research, and cleaning oil spills. On any system such as swarm robots, drones, or cars, our algorithm can adjust for prioritizing different objectives for low-power autonomous control, making efficient/optimal AV systems possible.

Hawaii and Pacific

The Effects of Environmental Conditions in Contribution to the Development of Tetracycline Resistance in Soil Bacteria

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The development of multi-drug resistant strains of bacteria is a complex issue in which human mortality rates caused by increasingly untreatable infections is a single facet of a larger problem. Compounding this is the rampant misuse of commercially available antibiotics in small and large-scale agricultural operations introducing antibiotic resistant bacteria into our food supply causing disastrous consequences for food costs, production, and security.

This study investigates farming and agricultural sites throughout Oahu to better understand what factors contribute to the presence of the tetracycline resistance genes *tetB* and *tetM* in soil bacteria. The study's findings suggest that sites where animals are being predominantly housed indoors are more likely to have bacteria containing tetracycline resistance genes *tetB* and *tetM*. Additionally, regardless of antibiotic use, resistance development is still a threat as these genes can persist within a bacterial population even after cessation of treatment.
These findings show that while methods of animal housing play an important role in combating the development of antibiotic resistance, certain areas may be predisposed to harbor resistant bacteria due to historic antibiotic usage in past agricultural operations. Moreover, further research should be conducted to observe how the *tetB* and *tetM* genes have evolved over time within the bacterial population. This poses a threat to both the conservation of culture through local agriculture and the health of the world on a larger scale.

Utilizing Microbiome Transplants to Improve Landscape-Scale Mosquito Suppression

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In Hawaiʻi, the mosquito Culex quinquefasciatus carries avian malaria, threatening extinction for Native Hawaiian forest bird species. The most effective and environmentally friendly method of controlling mosquito populations is the *Wolbachia* IIT. In this method, male mosquitoes are mass-reared in labs with

an incompatible strain of the bacteria *Wolbachia* (rendering them infertile when mating with wild mosquitoes) and released to mate with wild females. Eggs resulting from this cross are unviable, causing the wild population to decrease over time. However, lab-reared mosquito fitness is compromised, potentially due to being unable to gather a robust microbiome. This poses the question: Can the *Wolbachia* IIT method be improved by a microbiome transplant to improve lab-raised mosquitoes fitness? In this study, microbiomes were transplanted from wild sources into lab-raised mosquitoes and changes in developmental rate and physical fitness were measured. Then, genomic sequencing was used to analyze transplanted microbiomes. The field water transplant improved lab-raised mosquito developmental rate by 18% and physical fitness by 67%. This improved method of *Wolbachia* IIT has significantly improved efficacy, allowing for more *Wolbachia*-infected mosquitoes (improved developmental rate) with increased fitness to be released into the wild. The results of this study allow for improved success in the global use of *Wolbachia* in landscape-scale mosquito suppression efforts. Not only does this research have applications for statewide conservation efforts, but results from this project can be used to control other insects carrying vector-borne diseases like malaria and agricultural pests.

Using Aspirin to Mitigate Renal Toxicity of Lithium for Bipolar Disorder Using HEK293 Cells

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Lithium treatment, the first-line medication for bipolar disorder (BD) mania, is known to cause chronic kidney disease, reported in at least 20% of BD patients. To manage BD mania, physicians prescribe twice daily lithium carbonate (Li_2CO_3) pills, giving patients a blood serum level ranging from 0.4-1.2 mM, depending on the severity of their symptoms. Furthermore, the effects of lithium on a cellular level is largely unknown, and a satisfactory understanding of lithium-induced nephrotoxicity may lower the risk for patients with bipolar disorder. The purpose of this study was to quantify the effects of Li_2CO_3 at low therapeutic (0.6 mM) and high therapeutic (1.0 mM) doses on human embryonic kidney (HEK293) cells. Through an XTT assay, it was found that Li_2CO_3 causes a greater decrease in cell viability as the dose increases ($p<0.001$). The Lysotracker Green DND-26 assay showed Li_2CO_3 to cause lysosomal damage ($p<0.001$). Using the Wound assay, it was found that Li_2CO_3 inhibits cell migration ($p<0.001$). To mitigate these effects, aspirin in combination with Li_2CO_3 was tested because aspirin has been associated with a slower progression rate of kidney disease for regular users. It was found that 200-360 mg of aspirin increased cell viability, eliminated lysosomal damage, and stimulated cell migration ($p<0.001$). When tested alone, aspirin was shown to have no adverse effect on the HEK293 cells. Experimental results suggest that aspirin supplementation for bipolar disorder patients who take lithium treatment may reduce nephrogenic toxicity in patients.

The Effect of Culturally Tailoring a Literature-Based Intervention on the Mood and Engagement of Assisted Living Residents with Dementia

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With 29,000 people aged 65 years or older living with Alzheimer's disease in Hawaiʻi, finding non-invasive, culturally tailored (CT) interventions to improve quality of life is crucial. This study investigates if a CT

literature-based intervention affects mood and engagement of Japanese American assisted living residents with dementia. It also examines if residents respond better to Japanese or Hawaiian stories, facilitating conversation about how ethnicity and geographic location stimulates one's cultural identity. The hypothesis states that introducing a CT read-aloud and discussion will improve mood and increase engagement compared to a non-culturally tailored (NCT) intervention. Over six weeks, three CT and three NCT storytelling sessions were conducted, along with observations. However, the Smiley Face Assessment and Engagement of a Person with Dementia surveys were only administered during the last three sessions. Wilcoxon Signed Rank and Rank Sum tests were used to test for statistical significance of each respective test. Results showed CT interventions had statistically significant improvements in mood and engagement over NCT interventions. Japanese participants displayed higher engagement than non-Japanese participants during CT interventions. Moreover, the Hawaiian NCT session showed high efficacy, indicating the prevalence of a global identity. Aligning interventions with cultural backgrounds has clinical value in enhancing emotional well-being, underscoring the role of CT literature approaches in dementia care.

Sponge Studies: Assessing the Effects of Environmental Impacts on *Mycale grandis* Detritus Production, and Use as a Natural eDNA Sampler

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Coral reefs, containing over 25% of marine species, are vital ecosystems that support a diverse array of life and provide crucial resources for sustenance, supplying food for over 1 billion people globally. Despite constituting a significant portion of all cryptic biomass on coral reefs, marine sponges remain one of the most understudied organisms. This research sought to highlight both the ecological and scientific application of sponges, first by emphasizing their role in the Sponge Loop, a critical process by which sponges recycle nutrients and provide a basal food source of detritus to the reef. This experiment tested the effects of various pollutants and global warming on the Sponge Loop, to understand how this essential process is affected by environmental impacts. Significantly reduced detritus production was observed when *Mycale grandis* was exposed to microplastic pollution (-591.7%, $p<0.018$), sunscreen pollution (-492.5%, $p<0.021$), and increased temperatures (no detritus). eDNA is a modern technique used to assess the biodiversity of an ecosystem in a non-invasive way, fueling research in ecosystems such as the deep-sea. Due to the filter-feeding nature of sponges, it was hypothesized that they may be able to concentrate eDNA and serve as natural samplers. DNA from deep-sea sponges collected near Kingman and Palmyra Atoll was extracted, amplified, and then sequenced, resulting in the identification of multiple species including *Antedon bifida* and *Actinernus elongatus*. This research underscores the dual importance of sponges, serving as ecological keystones in nutrient cycling and potential tools for non-invasive biodiversity monitoring.

Heartland

The Role of Opioids in Accelerated Aging

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Background: Opioid abuse is associated with cognitive impairments and can even accelerate the process of aging, specifically age-sensitive brain functional networks in patients. Furthermore, morphine administration has been shown to result in synaptodendritic injury in rodent brains, leading to neurodegeneration and accelerated aging. Specifically, astrocytes have been shown by my lab to contribute to amyloidosis which could further contribute to both effects. However, the role of morphine in astrocyte-driven senescence leading to cognitive impairments remains an enigma.

Hypothesis: Morphine induces a senescent phenotype, which would contribute to accelerated aging seen in long-term opioid users.

Methods: I assessed morphine's impact on the expression of senescence phenotype markers (p16, p21, cell cycle arrest, β-gal activity, neuroinflammatory cytokines) *in vitro* in human primary astrocytes (HPAs) and validated this in an *in vivo* model of morphine-administered mice, using various experimental techniques.

Findings/Results: Morphine-exposed HPAs demonstrated significantly upregulated levels of these senescence phenotype markers as well as cell cycle arrest specifically in the S phase of the cell cycle. *In vivo* results from the hippocampi of morphine-administered mice supported these findings.

Conclusions: My findings demonstrate that morphine induces senescent phenotypes, which leads to widespread neuroinflammation and contributes to accelerated aging seen in opiate users.

Magnesmooth: Magnetizing the Ingenuity of Transportation

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In the modern day, transportation is everything. It's how we get to our daily destinations on time and quickly. Shock absorbers are being used on all vehicles on the road today. However, some modern shock absorbers are often labeled “rough riding” or “unstable.” First, shock dyno tests were performed on the pistons that I designed last year. It was hypothesized that the more voltage in an electromagnet, the stiffer the shock will react, and the less voltage, the softer the shock will feel. Next, I designed my own Electromagnetic Shock Absorber assembly to test with. My goal with the EMS testing was to see how the different weights and voltages would differ. Ten different tests were run with a self-designed Electromagnetic Shock Absorber assembly. Each test sector was designed with more weight and more voltage to test the differences between the different weight-to-time ratios. All of the trial testing of the EMS (Electromagnetic Shock Absorber) was highly consistent. Significant differences ($P<0.05$) were seen between all groups indicating that weight and voltage affect piston travel time. I was highly impressed by how consistent the times were on the EMS results with the fluid I designed. These results supported the hypothesis. The more voltage you have in the electromagnets, the stiffer the shock will be, and the less voltage that you have, the less the shock will react to bumps and feel softer.

An Analysis of the Correlation between Stock Price Fluctuations and Social Media Traction

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This paper aims to identify the correlation between stock performance and social media traction during 2020. It analyzes data from three different investment-focused communities within the social media platform Reddit. This data is compared to the historical financial data of six stocks across six different industries in the year 2020. The number of posts with the name of the stock within the original post each week is compared to the absolute percent change between market open to close for that week. As a control, data from the same time frame on the SPDR S&P 500 ETF Trust is used for comparison with the experimental data. All of the stock price information was taken from Yahoo! Finance. This study reveals that there is a statistically significant positive correlation between stock price change and number of Reddit posts each week. The observed correlation between stock performance and social media patterns has a significant impact in determining future stock volatility and predicting short-term investor sentiment.

Depolymerization of PLA Plastics: A Novel Investigation of the Effect of Iron and Zinc Catalysts on Biodegradable Compounds

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The use of biodegradable plastics is becoming more and more widespread, and this project's aim is to depolymerize manufactured PLA products in order to obtain reusable polylactic acid. Zinc and iron were used as catalysts and their efficacy at decomposing the plastics was determined at the end of the experiment.

Prior to the addition of the catalysts, the PLA plastics were submerged in a mixture of hydrochloric acid and the enzyme, pepsin, to simulate the breakdown of amino acids in the stomach, initially breaking the surface layer of the PLA material. Temperatures of 55°C-150°C were reached at ten-minute intervals and the external results of the trials were recorded and then the chemical breakdown was analyzed.

The glass liquid stage was reached at 60°C-65°C, less odor was observed in the trials of zinc than of iron or the control group, hinting at the chemical change occurring at this point. Zinc was the most efficant catalyst, 80% of the PLA material was successfully decomposed and an amount of polylactic acid was obtained during the heating process. At large, zinc can be used as a cheaper, albeit not as effective alternative to ruthenium and other catalysts that depolymerize plastics.

A High Rate of Human Error in Early Detection of Small Brain Metastases Suggests a Basis for Development of Artificial Intelligence Recognition Technology

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Brain Metastases carry poor prognosis in cancer patients with their rapidly growing nature. Early identification of these tumors is crucial in improving patient survival. This investigation aims to study the rate of human error in missing early brain metastases and factors associated with the threshold of sensitivity of human eyes.

Data from the University of Nebraska Medical Center was used. The database included patients with new brain metastasis diagnosed based on brain magnetic resonance imaging (MRI) who also had previous MRI scan(s) 1-6 months before diagnosis and no exposure to whole-brain radiotherapy. The brain MRI used for diagnosis of brain metastasis and the MRI performed 1-6 months prior were reviewed. Based on the

location of the newly diagnosed tumor, the corresponding location in the previous MRI was assessed for a missed incidence of a preexisting tumor. The sizes of the missed tumors were then measured to assess the threshold of human eyes in detecting metastases.

The percentage of missed metastases was 44% (56/126). The mean size of missed metastases was 3.0 millimeters (range 1.2 to 7.7 mm). No clinical factors were significantly associated with a higher rate of missed diagnosis. The most likely reason for the missed diagnosis is the tiny size although visual distraction seems to play a role including adjacent contrast-enhancing structures such as blood vessels.

The results show a high rate of human error for missing small metastases. These results justify the development of artificial intelligence-based recognition to assist neuroradiologists in diagnosis.

Illinois-Chicago

A Comparison of *Zingiber officinale* Mediated Synthesis of Copper Nanoparticles and Chemically Synthesized Copper Nanoparticles Through Their Effects on *Drosophila melanogaster* Locomotion for In Vivo Medical Applications

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This experiment studied the effects of ginger-mediated and chemically synthesized copper nanoparticles (CuNP) on the model organism Drosophila melanogaster (D. melanogaster). Nanotechnology is a rapidly evolving field in which nanoparticles (NP) are pioneering developments, particularly in medicine. Metal NPs have been shown to display antibacterial, antiviral, and anticancer properties. However, the in vivo cytotoxic effects of these particles are not fully known. Much research has suggested the incorporation of biological materials to increase the biocompatibility of these particles. To test this hypothesis, this experiment investigated chemically synthesized CuNP compared to ginger-mediated CuNP. D. melanogaster was analyzed to further understand the effects of CuNP on living organisms. After NP characterization using TEM, DLS, and UV-visible spectroscopy, 3 separate dosages of the NP were incorporated into fly media. A climbing assay was used to observe the effects on locomotion and geotaxis of the D. melanogaster adults and their larvae. A 2-way analysis of variance (ANOVA) showed no statistically significant differences in climbing ($p > 0.1$ for both copper and ginger CuNP) however did find substantial evidence to attribute variation in larval crawling to CuNP treatment when compared with a control ($p<0.001$). These findings support the concerns of present research regarding the toxicity of chemically synthesized NPs in particular. With further research, biologically synthesized NP could be developed and implemented in academic, commercial, and military settings as biologically compatible antimicrobial, antiviral, and anticancer agents.

Optimizing Bioremediation of Lead (II) in Wastewater with *Lactobacillus acidophilus* and Chitosan Across Variable pH Levels

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The presence of lead ions in wastewater is a growing concern worldwide, but especially in impoverished communities, where approximately one-third of children have elevated lead levels in their bloodstream. The current remediation techniques are expensive, inefficient, and inaccessible to regions that require quick and dependable removal of toxins from water, particularly those economically challenged communities. Novel filtration techniques have been investigated, including one involving lactic acid bacteria (LAB) ubiquitous in living organisms, ranging from dairy products to the human gut. LAB carries a negative charge, facilitating metal ion binding due to the positive charge of Pb (II). This experiment aimed to examine the interaction between the specific LAB, *Lactobacillus acidophilus (L. acidophilus)*, and chitosan at varying pH levels of lead (II) contaminated wastewater. The hypothesis asserted that the addition of d-glucosamines, such as chitosan, and the manipulation of the acidity of the solution could enhance the negative charge, thereby increasing the absorption of lead. The results of this experiment demonstrated that while both *L. acidophilus* and chitosan exhibited absorbent properties individually, the combination of *L. acidophilus* and chitosan was more effective in absorbing lead in almost all groups tested (ANOVA $p < .001$), and that their synergy was enhanced the most in basic environments. Therefore, the null hypothesis was rejected. These findings have promising implications for larger-scale wastewater purification, particularly in communities that do not have access to standard lead removal techniques due to economic constraints.

Analysis of Methanol and Hydrogen Interactions Under High Pressure Using Raman Spectroscopy

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In this study, I compared two samples: one with pure methanol and another containing a methanol-hydrogen mixture. My goal was to see if the interactions between hydrogen and methanol at high pressures would result in a clathrate, a structure where the liquid methanol would form a cage around the hydrogen gas. To model a high-pressure environment, the samples were put into a diamond anvil cell (DAC), which was able to compress the materials up to 12.0 gigapascals. Raman spectroscopy analysis was used to determine the vibrational modes of the molecules in my samples — this allowed me to yield information about the chemical structure and molecular dynamics of both the pure methanol and the methanol-hydrogen mixture as they experienced increasing pressure. The Raman spectra showed changes in the methanol-hydrogen mixture that point to a clathrate-like structure beginning to form at the mixture's freezing pressure of 6.5 GPa. The most drastic change occurred in the vibrational mode of the hydrogen molecule. This study provides new information on high pressure behavior of simple hydrogen-bonded liquids, as well as how organic molecules interact with hydrogen in extreme conditions. This could potentially contribute to further studies relating to planet-forming processes, especially as more organic molecules are discovered in the material surrounding stars. The results of this study have potential implications in planetary systems such as TW Hydrae, where methanol makes up the composition of the protoplanetary disk.

Deep Learning Based Automated Platform for Sarcopenia Assessment and Outcomes Analysis in Head and Neck Cancer

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The body composition status, which characterizes the levels of muscle and adipose tissue in a person's body, is closely linked to cancer treatment risks and survival. Sarcopenia, describing muscle depletion, is a well-studied prognostic factor in patients diagnosed with head and neck cancers (HNC). Sarcopenia is typically assessed by measuring skeletal muscle index (SMI) derived from muscle segmentation of Computer Tomography (CT) imaging. However, manual segmentation is time-consuming, prone to human variability, and not practical for routine clinical use. In this study, a fully automated deep learning (DL) based platform was developed to accurately segment the skeletal muscle and adipose tissue at the third cervical vertebrae level (C3) from CT scans. This platform enables precise sarcopenia measurement and an evaluation of its relationships with overall-survival and treatment induced toxicity outcomes. A multi-institutional study was conducted using de-identified data from patients undergoing primary radiation therapy for HNC at three major North American comprehensive cancer centers. Median Dice Similarity Coefficient (DSC), which measures pixel-wide agreement with ground truth, was 0.91 for predicted skeletal muscle segmentations and 0.86 for adipose on the internal test set, with a 95.5% acceptable rate on external validation testing, indicating excellent predictive ability and generalizability of DL models. Predicted SMI values were highly correlated with manually annotated values, with Pearson $r = 0.98$ ($p < 0.0001$) for patients across datasets. In multivariable Cox-regression analysis (n=342), SMI-derived sarcopenia was associated with worse survival and longer PEG tube duration. This platform can integrate sarcopenia assessment into clinical treatment decision-making for individuals with HNC, ultimately leading to improved outcomes.

Effects of Ampicillin and Amoxicillin Exposure on the Nervous System Regeneration of *Schmidtea mediterranea*: A Novel Toxicology Assessment with Applications for Global Neonatal Health

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Ampicillin and amoxicillin are two highly impactful penicillin antibiotics utilized to treat neonatal sepsis and other widespread diseases, improving the health of millions of young individuals across the globe. Recently, human and animal based studies have identified an association between early life exposure to first generation penicillins and dysregulation of several neurological pathways. However, this association has not yet been established for ampicillin and amoxicillin, thoroughly tested third generation penicillins related to but chemically different than their first generation counterparts. This experiment utilized a novel animal assessment, the regenerative asexual planarian *Schmidtea mediterranea* (*S. med*), to better understand the neurological effects of early life ampicillin and amoxicillin exposure. *S. med ChAT* (choline acetyltransferase) and *sert* (serotonin transporter) genetic expression after exposure to ampicillin or amoxicillin during brain regeneration was noted with colorimetric analysis and compared to the genetic expression of a negative control not exposed to any antibiotic. *sert* clusters were numerically quantified.

Ultimately, worms exposed to ampicillin and amoxicillin exhibited no statistical difference in visible *sert* expression from those without any exposure to antibiotics (Kruskal-Wallis ANOVA, p=0.9623). These findings reflect the results of similar studies and support the safety of ampicillin and amoxicillin. This experiment also investigates the use of *S. med* to determine the toxicity of certain substances. After further research, these worms have the potential to be utilized as comprehensive developmental toxicology models in commercial and academic settings.

Illinois

Optimizing Memory via Real-Time Monitoring of Neural Data with Adaptive Brain Stimulation Machine Learning Algorithms

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Mentor: Dr. James Kragel, University of Chicago

In this research, I aim to test how stimulation of distinct brain systems affects memory organization and whether such stimulation exhibits state-dependent effects. Aging and neurological disorders lead to neurodegeneration that decreases our ability to remember events. Deep brain stimulation (DBS) has emerged as a potential solution by stimulating neurons with electricity to enhance neuronal activity during memory tasks. I hypothesize that DBS can improve memory when targeted towards poor memory encoding states by influencing semantic organization.

This study utilized data from 38 neurosurgical epilepsy patients with implanted electrodes performing the free-recall tasks with and without stimulation. Spectral data from each electrode were used in a user-specific algorithm based on the random forest to predict the memory encoding state at an average area under the curve (AUC) of 98% across all subjects. Next, a DBS success classifier based on the random forest predicted improvements in memory outcomes when stimulation was applied based on pre-stimulus memory encoding state qualities found through the user-specific algorithms, achieving an average of 84% AUC. This study established that stimulation targeted at memory networks enhances memory by targeting poor encoding states. In addition to state dependency, it was discovered that stimulation applied to the left lateral temporal cortex (LTC) enhanced the brain’s ability to create semantic clusters and recall performance. The combination of these two algorithms with the identification of the positive effects on the left LTC indicates a promising relationship between targeted DBS and memory enhancement, proposing a new treatment for improved episodic verbal memory.

Novel Treatment as Reduction of Oxidative Stress Using Mixed Antioxidants for Alzheimer's Disease Symptoms

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The purpose of this research was to investigate if the combination of the antioxidants ferulic acid (FA), curcumin, and caffeine decreased oxidative stress (OS) in order to ascertain if mixed antioxidants facilitate a greater decrease of AD symptoms due to the correlation between OS and AD symptoms. Determining novel therapeutics for AD is especially important because current treatments are expensive, have low success rates, as well as have undesirable side effects. A potential novel pharmacotherapeutic treatment based on this experiment is hoped to address the current gap in AD treatment. The procedure of the experiment began with incorporating individual antioxidants into agar to form the positive control group, along with a negative control group with no antioxidants. Then, synchronized, genetically modified adult CL2166 *C. elegans* worms were placed into the control plates and were observed for a week by taking pictures under fluorescent light. This process was repeated for mixed chemical plates then analyzed at the end of the experiment. Overall, it was determined that the novel mixture of caffeine and FA as well as curcumin and FA decreased OS therefore rejecting the null hypothesis. The one-way ANOVA *p* value was below 0.0001 and individual t-tests conducted concluded significant values at ($p<0.05$) for the groups caffeine with FA and curcumin with FA. With future research it is likely that a novel pharmacotherapeutic treatment may be produced that is accessible, effective, and inexpensive.

Analytic Modeling of Exoplanet Detection via Gravitational Lensing and Orbital Motion

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Exoplanet detection is a growing field. Improvements to detection methods are likely to be more wide-ranging as telescope acuity increases. Due to this, the effect of orbital motion on gravitational microlensing events was analyzed to form a basis for specialized exoplanet detection in the near future. The produced effects of orbital motion-influenced gravitational lensing systems on exoplanet-star systems were considered. The Python packages pyLIMA and MulensModel were used to simulate many microlensing events with mathematically determined parameters. Each model simulated the optical effects of a three-body binary lens-source system with differing mass ratios between the two lenses involved. Through all models, all parameters remained constant other than the mass ratio. Light curve differentiation based on mass ratio adjustment was noted, and the two packages were compared. Significant aberrations in the pyLIMA package were noted as opposed to the MulensModel package, and a relationship was identified between mass ratio and detection rate. A mathematical fit to map mass ratio to detectability was also established, allowing significant gaps in the literature to be filled with regard to both detection and low-mass identification in microlensing events. Identifying this relationship provides the foundation for a larger knowledge base for more acute microlensing surveys, like those of the Nancy Grace Roman Space Telescope in 2027.

Novel Convolutional Neural Networks for Improved Accuracy in User-Accessible Brain Tumor Detection and Classification

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Mentors: Mr. Sean Fu, Tesla; Mr. Thomas Walton, Georgia Tech; Dr. Haohan Wang, UIUC

Effective treatment for brain cancer is aided significantly by the rapid detection of tumors. Traditional detection methods involving the manual inspection of Magnetic Resonance Imaging (MRI) scans have been established to be slow, consuming large amounts of time both for the specialist and the patient. The purpose of this design investigation was to propose and develop three artificial intelligence (AI) models, specifically, convolutional neural networks (CNNs), employing novel techniques to quickly and accurately detect the presence and type of brain tumors from MRI scans. The goal was to provide medical professionals with a faster alternative compared to traditional, manual detection methods by overcoming inefficiencies and reducing human error. The design was also able to address various gaps and limitations in existing studies, most notably, the lack of a user interface (UI) for easy and practical accessibility. Therefore, in this design, the highest performing CNN, utilizing the pretrained VGG19 architecture—with a validation accuracy of 98.06% and validation loss of 0.02—was integrated into a minimalistic, open-source UI website using the Gradio library, enabling hospital workers to upload MRI images with ease for tumor identification, facilitating real-world applications and usage in various understaffed medical settings.

Algorithmic Design and Computational Modeling Using Dynamic Spectrum Allocation Techniques to Optimize Bandwidth Management in Wireless Communication Systems

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This study aims to address the pressing need for efficient spectrum management methodologies in wireless communication systems by developing innovative sorting and allocation algorithms. Leveraging Dynamic Spectrum Allocation (DSA) techniques, this research seeks to devise strategies to optimize the utilization of bandwidth within existing spectrum space, ultimately reducing the need for spending and network infrastructure expansion. Ensuring thorough coverage of DSA techniques, 5 distinct transmitter sorting algorithms were programmed and tested across 8 performance metrics designed to measure specific capabilities. For consistency, a single bandwidth allocation program was designed to 'pack' transmitters starting from the left endpoint of the spectrum space. Progressively varying the transmitter count, Northwestern's Quest Supercomputer performed the final computation, using 64 gigabytes of RAM and running for ~10 hours. The sorting algorithms based on the product of radius and bandwidth (Power Sort) and based on the most signal interference (Most-Overlap Sort) were most efficient, performing well in two key categories. Most-Overlap Sort and Power Sort produced average feasibility values of 0.675 and 0.664, respectively, scoring a 8.6% – 10.6% improvement in feasibility performance. Consequently, the greater maximum bandwidth remaining indicated highly efficient allocation within spectrum resources; Power Sort and Most-Overlap Sort took up 8.888 and 9.042 bandwidth intervals, respectively, performing ~6% better than control. Most-Overlap Sort allocates the most 'problematic' transmitters first, gaining an edge in end feasibility. Power Sort's success can be attributed to its prioritization of bandwidth/area-hungry transmitters, simplifying the allocation of minor transmitters in the final stages.

Indiana

Identifying Pyroptosis-Related Genes in Alzheimer's Disease Based on Bioinformatics Analysis

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Alzheimer's disease (AD) is the seventh leading cause of death in the United States, with over 6 million Americans reported in 2023. Recent studies have shown the association between AD and inflammation. Pyroptosis, a newly discovered form of cell death, is associated with inflammation and has been found to be involved in AD. However, the exact relationship between pyroptosis and the pathology of AD remains unclear. The purpose of this project was to identify the pyroptosis-related genes (PRGs) associated with AD and to analyze their roles in the disease pathology. To this end, microarray data analysis was performed on the GSE48350 dataset containing the post-mortem brain tissue samples from 80 AD patients and 173 healthy individuals. The differentially expressed genes that intersected with 52 PRGs from published literature were noted as differentially expressed pyroptosis-related genes (DEPRGs), which included 4 up-regulated and 4 down-regulated genes. Gene Ontology and Kyoto Encyclopedia of Genes and Genomes enrichment analyses revealed that the DEPRGs were enriched in the positive regulation of cysteine-type endopeptidase activity involved in the apoptotic process, cAMP-dependent protein kinase complex, cysteine-type endopeptidase activity involved in apoptotic signaling pathway, and Legionellosis. Four hub genes, SCAF11, CASP8, CYCS, and TP53, identified using Cytoscape software, were significantly expressed in AD patients, and their diagnostic and predictive value was evaluated using receiver operating characteristic curves. These findings suggest that DEPRGs play a crucial role in the development and progression of AD and could be used as potential diagnostic biomarkers and therapeutic targets for AD treatment.

Quantum Annealing for the Set Splitting Problem

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This work explores a novel application of quantum annealing to solve the Set Splitting Problem and common variants, including Max Set Splitting and Weighted Set Splitting. The Set Splitting Problem is applicable to DNA micro-array data analysis, graph based cybersecurity, and other fields. I propose a quadratic unconstrained binary optimization (QUBO) problem formulation of the Set Splitting Problem in order to encode any given problem onto a Quantum Annealing Computer. The key contribution of the work consists in formulating penalty functions that ensure the ground state of the QUBO Hamiltonian corresponds to valid solutions that split the input subsets. This approach scales linearly in terms of the number of logical qubits needed relative to problem size. Empirical tests of the proposed solution show convergence to globally optimal solutions, with high accuracy rates over repeated trials. One limitation of the proposed solution is in handling sets with cardinality above 3, in that the achieved solution might not be optimal; however, solution optimality can be checked. Hardware limitations of current quantum annealers lead to an exponential rise in required physical qubits, versus the theoretical linear increase, although this can improve with future developments. Further work is needed to enhance formulation robustness, reduce qubit requirements for embedded problems, and to conduct more extensive benchmarking. Quantum solutions to the Set-Splitting problem lead to reduced time complexity versus classical solutions, and may accelerate research in biology, cybersecurity, and other domains.

Crystallization and Morphology Tailoring via Functionalized Ligands for Efficient and Stable Perovskite Solar Cells

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Perovskite solar cells have been regarded as one of the most promising alternatives to conventional polycrystalline silicon solar cells due to their excellent photovoltaic properties, flexibility, and relatively low cost. However, there is still a big gap in transitioning laboratory scale devices to industrial large area solar cell modules. Here, slot-die coating excels, mainly benefiting from its high compatibility with the industrial used roll-to-roll (R2R) method and low material cost. But, the enlarged device area makes the decomposition initiated by pinholes and defects more significant, largely affecting the performance of the devices. Most researchers limit their attention to regulating the crystallization process of perovskite film during the slot-die process. Therefore, defect passivation is often neglected because of extra surface coating processes, additional complexity, and costs. Hence, it is meaningful to find a strategy to modify the crystallization and suppress detrimental defects.

Herein, it’s hypothesized that a long-chain ligand with fluorine groups can effectively tune the crystallization route and stabilize the surface of perovskite films. During crystallization, the fluoride group on the ligand which can coordinate with lead and the amine group will interact with the inorganic part of perovskite, thus modifying the crystallization process. Preliminary results show that incorporating 2-(5‴-fluoro-3‴,4′-dimethyl-[2,2′:5′,2″:5″,2‴-quaterthiophen]-5-yl) ethan-1-ammonium (F4Tm) iodide can regulate the crystallization process and increase the grain sizes. As a result, the solar cell device performance and stability increases with the assistance of additive F4Tm. The results from the small-area devices show great potential of applying F4Tm ligand in slot-die printed perovskite solar cells.

Balancing Misclassification Costs (BMC) in Imbalanced Classification

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Classification tasks in machine learning, essential for applications ranging from fraud detection to medical diagnoses, frequently encounter the challenge of imbalanced datasets. These imbalances can skew predictions towards the majority class, risking oversight of vital minority instances and carrying significant real-world consequences. Established methods, such as Logistic Regression, Support Vector Machines, and ensemble techniques, offer solutions to classification challenges but often struggle with imbalanced datasets. Conventional strategies like resampling and cost-sensitive learning provide value but come with issues like overfitting, data loss, and increased computational demands. A notable disconnect also exists between estimation procedures and evaluation metrics, further complicating the task of accurately gauging model performance.

In this work, we present the Balancing Misclassification Costs (BMC) algorithm, an innovative approach designed to adeptly tackle the challenges posed by imbalanced datasets. Our method integrates misclassification costs within a unified optimization framework. Capitalizing on rigorous theoretical proof, we have also devised an efficient estimation procedure. Through detailed simulations and its application to a cancer diagnostic dataset, we underscore BMC's superiority over conventional methodologies.

Potential Microrna Biomarker Panel for Predicting Evolution of Pancreatitis to Pancreatic Ductal Adenocarcinoma

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PDAC (pancreatic ductal adenocarcinoma) is the 3rd most common cause of cancer deaths and is projected to be the 2nd most common cause by 2030 even as it comprises only 3.2% of all cancer cases. The most important predictor of survival is resection of early-stage cancer. PDAC risk is 15-16 fold for chronic pancreatitis. A differentially expressed microRNA (DEM) serum panel is identified, compared, and extracted that could predict risk of progression to PDAC from pancreatitis. Two microarray Genomic Spatial Event (GSE) datasets containing pancreatitis, PDAC, and control samples were used to extract DEM common to both pancreatitis and PDAC. 8 smaller subgroups of DEM were derived from bioinformatics methods such as ROC/AUC of expression values, up and downregulated clustering, correlation analysis, miRNA interaction networks, target gene prediction tools, target gene interaction and functional enrichment analysis for all target genes and top modules, as well as decision tree/cross-validated random forest machine learning models. The DEM original group (n=22) and the smaller subgroups predicted the risk of pancreatic cancer vs control in a validation set consisting of six other GSE datasets. The original 22miRNA panel had the highest accuracy, F1, precision and recall, followed by subgroup 6 derived from the target hub genes with the highest interaction (hsa-miR-28-3p, 320b, 320c, 320d, 532-5p, and 423-5p). A new serum microRNA biomarker panel predicting evolution of pancreatitis to pancreatic ductal adenocarcinoma, and its associated pathways, has been identified, that also performed well in distinguishing pancreatic cancer (with or without pancreatitis risk factor) from control.

Intermountain

Treating Noise-Induced Hearing Loss Through Inner Ear Permeable Retinoid

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In the modern era, we are all exposed to increasingly harmful environmental and occupational noise. Despite the fact that there are currently 1.1 billion young people around the world who are susceptible to noise-induced hearing loss (NIHL), there are no treatments available. NIHL is triggered through the loss of inner hair cells (IHC) as a result of various pathways including inflammation, oxidative stress, and calcium overloading. Retinoids counteract these through their varied effects on biological processes modulating cellular differentiation and proliferation. Unfortunately, these IHCs are in the inner ear which is protected by the round window membrane (RWM). Previously, treatment included perforation of this membrane, but this ultimately resulted in complications such as drug displacement from leaking cerebrospinal fluid. This project conjugated a chosen retinoid already in use in the pharmaceutical market to hyaluronic acid--a very permeable molecule. Qualitative analysis demonstrated that the retinoid permeated through models of the RWM. An ideal retinoid that is able to resist the strain of the conjugation process is able to reach and naturally permeate into the inner ear, allowing for long-term efficacy in its treatment with safe and effective dosing. This novel drug delivery system may be on the path to being a legitimate treatment for a previously untreatable medical affliction affecting billions. Allowing this retinoid to be directly exposed to the IHCs, will help further investigate the disease's pathways, demystifying one of the largest unmet medical needs.

Understanding Gaze Control Mechanisms in Healthy Individuals versus Individuals with Multiple Sclerosis

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Multiple sclerosis (MS) is the most common non-traumatic neurological disease in both North America and Europe. People with multiple sclerosis (PwMS) experience debilitating symptoms such as dizziness and balance deficits. Previous literature indicates that the vestibulo-ocular reflex (VOR) has correlation with dizziness when it is not functioning properly, due to its role in gaze stabilization. For the procedure, two tests were performed that are common in vestibular research, video head impulse testing (vHIT) and computerized dynamic visual acuity (cDVA). vHIT consists of abrupt head thrusts while participants attempt to keep their visual field fixed on a static point, this test will generate metrics for VOR gain (eye velocity/head velocity), gaze position error (GPE [eye position vs. head position]), and saccade latency (amount of time for the first saccade to generate). For cDVA, participants attempted to identify different letters, first while their heads were stationary, and secondly with a self-generated head rotation. In VOR gain, we saw significant differences in gain metrics, but saw greater decreases on the vertical planes of motion than horizontal planes. This suggests that PwMS have worse function in the pitch plane than the yaw plane. Additionally, we saw that during vHIT, participants with MS would still be off target by approximately half a degree at the 400 millisecond mark. cDVA results indicated that MS has little effect on this test. This suggests that rehabilitation programs for PwMS should focus more on pitch movements than yaw movements, seeing as their pitch results were considered abnormal.

A Novel Method of Genomic Analysis to Determine Virus Origins

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Ever since the SARS-CoV-2 (“Covid-19”) pandemic, interest in viruses has drastically increased. While viruses have been a subject of historical research, significant gaps remain in our understanding, particularly regarding their origin. This research investigates three commonly accepted theories on virus origin. The first theory includes the progressive hypothesis, which states that viruses escaped through horizontal gene transfer from their host cells. Then, the regressive hypothesis states that viruses “lost” essential genes over time, becoming an intracellular parasitic organism dependent on hosts for replication. The virus-first theory states that viruses originated before cells, and although much debate has occurred on this theory, it has still not been officially disproved, which is the reason behind its inclusion in this research study. This research was done with *Homo sapiens* and *Felis catus* genomes. Using the Mean Squared Error test and other statistical methods to compare the level of genetic similarity between viral genomes, this study concludes that the progressive theory is the best fit for viruses that affect the immune system. The new method of genomic analysis used in this research can be repeated with the genomic sequences of any virus to help scientists determine a more comprehensive evolutionary timeline. This can help with the creation of better immune system defenses against these viruses and vaccine development, improving global health worldwide.

The Effects of Subconcussive Head Impacts on Contact Sport Athletes – Sports-Related Concussion (SRC) Assessment Techniques

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A subconcussive head impact is defined as a blow to the head that does not cause noticeable clinical signs or symptoms of concussion. Such events carry a latent potential for neurological damage and should be of particular concern in contact sports. Existing assessments for sports-related concussions (SRC) predominantly focus on explicit, self-reported symptoms and more obvious neurological impairments, leaving signs of subtle neurologic deficits largely undetected. Growing research illustrates that existing SRC evaluations lack sensitivity in identifying residual neurological impairments following head impacts. This study evaluated whether contact sport athletes exhibit signs of neurologic deficits immediately after suffering subconcussive blows when assessed with more precise tests. Nineteen boxers (contact athletes) were administered six tests before and after a competitive match, and nine swimmers (non-contact athletes) were assessed with the same tests before and after 20-30 minutes of high-intensity swimming to control for the possible confounding variable of fatigue. Three of the tests proved to be unreliable markers of soft neurologic signs or fatigue. For each of the reliable tests, the differences between swimmers and boxers were statistically significant, with boxers exhibiting signs of neurologic deficits following their match. The results suggest that fatigue does not impact an athlete’s ability to perform the administered assessments. Changes exhibited by boxers are attributable to subconcussive blows, indicating that these head impacts can cause immediate signs of neurologic deficits when athletes are assessed with more precise techniques. These results challenge the current definition of a subconcussive blow and support the improvement of SRC assessments.

microRNAs in Action: Regulation of Feeding Behavior

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Glutamate is a major neurotransmitter involved in signaling in the brain including between the paraventricular nucleus of the hypothalamus and nucleus accumbens. Caloric intake is regulated by these structures. Thus, dysregulation of this process can lead to overconsumption, causing obesity. Vesicular glutamate transporter (VGLUT) levels regulate packaging of glutamate. VGLUT transcripts are regulated by microRNAs (miRNA), which play key roles in the post-transcriptional regulation of gene expression. miRNA sponges contain numerous high-affinity binding sites for a specific miRNA to prevent it from binding to its target. In this project, we tested the hypothesis that higher levels of glutamate released by VPM4 neurons promote feeding, and that glutamate levels were regulated by miR-1000 and miR-1008, which target VGLUT. Using the binary Gal4-UAS system to express miRNA sponges in just one pair of neurons in the Drosophila brain, the VPM4 neurons, we conducted assays with control groups and experimental groups. There was significantly less food intake in the experimental group with miR-1008 knockdown in VPM4 neurons, suggesting that glutamate functions here as an inhibitory neurotransmitter. There was no difference in food intake for flies with miR-1000 knockdown indicating specificity in miRNA function, narrowing down which miRNAs may be most effective in potential treatments. Overall, this project demonstrates miRNA-1008 regulates food intake and further experiments will demonstrate this regulation is through VGLUT and glutamate. These findings can be used to further research on effective and non-invasive treatments for human obesity.

Kentucky

Design of a Low-Cost, Low-Inertia, Backdrivable Humanoid Upper-body

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General purpose humanoid robots have long been envisioned for a plethora of applications such as disaster relief, industrial automation, agriculture, or elderly assistance. A humanoid form for a robot allows for optimal utility and mobility in a world where the environments and tools are designed around humans. However, in the current field of robotics, conventional robot actuator design struggles with three key limitations. A lack of backdrivability in dynamic tasks (undefined and quickly changing forces and trajectories) (Wensing, 2017), a lack of humanoids that are low cost & highly backdrivable, and a prohibitively high cost of research on humanoids (Kim et al., 2015). Thus, this research sought to tackle these problems in the design of a low-cost, low inertia, high impact mitigation, humanoid upper body. The design implemented 3D printed Quasi-Direct Actuators designed on Autodesk Fusion360, with high torque BLDC motors inspired by MIT's proprioceptive actuator on the MIT Cheetah. In addition, a PID controller with IMF dampening was employed with off the shelf electronics culminating in a cost of ~1000 dollars. This was <2% of the cost of current humanoids that can range from 50k - millions of dollars to buy or research. The designed humanoid was able to achieve its research goals and achieved its benchmarks for functionality, backdrivability and cost, and developments in this research has the novel potential to allow for the widespread accessibility of humanoid research due to its low cost, and advance the frontiers of humanoid research, especially in human-robot interaction.

A Novel Breath Analysis Method for the Diagnosis of Heart Failure

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Currently, 6.2 million adults suffer from heart failure (HF), with only 30-40% surviving one-year post-hospitalization and a 30-day readmission rate of 23%. The urgent need for an affordable, specific, non-invasive, and portable screening test to rapidly diagnose HF has led to a novel diagnostic approach using breath analysis and machine learning. In this study, twenty-seven HF patients and thirty healthy controls were enrolled and provided exhaled breath samples through a microfabricated microreactor chip coated with 2-(aminooxy) ethyl-N,N,N trimethylammonium to capture carbonyl compounds in the breath. Carbonyl compounds were then analyzed by ultra-high performance liquid chromatography-mass spectrometry. There were unique metabolic fingerprints associated with HF, indicated by the altered concentrations and patterns of twelve carbonyl compounds. Patients with HF showed significantly higher levels of compounds such as acetone, pentanal, acetic acid, caproic acid, acrolein, and 3,4 methylenedioxyamphetamine while exhibiting lower levels of others like 2-butanone, pentanone, ethyl propionate, cyclohexylacetone, methyl acrylate, and 4-hydroxy-2-hexenal compared to healthy controls. Sparse partial least squares discriminant analysis and 2D scores plot allowed complete differentiation of HF patients from healthy controls. Random forest machine learning algorithm achieved an average area under the curve of 0.99, validating the hypothesis and underscoring the potential of breath analysis combined with machine learning as a non-invasive diagnostic tool for HF. Top 5 features in the machine learning algorithms were acetone, cyclohexylacetone, pentanone, 2-butanone and ethyl propionate. In conclusion, this study provides compelling evidence for the use of breath analysis and machine learning in diagnosing HF.

Immunomodulatory Response of Neem Leaves Extract and its use in Treating Chronic Inflammatory Diseases

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Inflammation is the process our body uses to combat infection, allergy, or injury. Solutions available have many side-effects and are not safe for long-term use. The goal of this project was to find a natural anti-inflammatory specifically targeting neutrophils and macrophages. The hypothesis was that medicinal plant extracts have compounds that attenuate the response of activated leukocytes to resolve inflammation. To test, neem leaves extract was prepared using 80% methanol for extraction. First, the extract was tested on neutrophils and macrophages and showed no toxicity. Then, the extract was tested on neutrophils for intracellular reactive oxygen species production (ROS) and degranulation upon stimulation with Phorbol Myristate Acetate (PMA). Results showed that the extract significantly reduced ROS production and inhibited granules movement in PMA stimulated neutrophils. The extract was tested on cells for production of cytokines in response to PMA or lipopolysaccharide (LPS). In the presence of extract, a significant reduction in the expression of pro-inflammatory cytokines was observed when compared to PMA or LPS stimulated leukocytes. Furthermore, the ability of neem extract to accelerate apoptosis in neutrophils and its clearance by macrophages was evaluated. The treated neutrophils showed accelerated apoptosis and these cells were more efficiently removed by macrophages. The effect of the extract on the metabolic activity of HaCaT skin cell line was checked and showed no effect on the cell metabolic activity or

proliferation. This project concludes that neem extract quietens the activated neutrophils and macrophage responses and has potential to be a safe, effective anti-inflammatory substitute.

Lithium Iron Phosphate Promotes Tumor Cell Growth by Shaping Mitochondrial Function

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Mentor: Dr. Jing Yao Mu

Water pollution is a critical threat to human health as it can lead to increased cancer risk. More than 22 carcinogens can be found in the drinking water, including heavy metals such as lead, mercury, and cadmium. As the use of lithium-ion batteries is dramatically increasing, it is essential to identify its uncertain potential health hazard. This study investigated the tumorigenesis potential of lithium iron phosphate ($LiFePO_4$), widely used in electric vehicle batteries. An MTT proliferation assay was used to test the influence of $LiFePO_4$ on the growth of cells involving the colon, breast, lung, and brain, four common cancers. The Seahorse Assay and transmission electron microscopy (TEM) were utilized to identify the impact of $LiFePO_4$ on mitochondria-relative cell energic metabolism and mitochondrial ultrastructure, respectively. The results suggested that $LiFePO_4$ enhances human MDA-MB-231 and mouse 4T1 breast cancer cell growth but doesn't affect colon or brain cancer cell proliferation. Although a high concentration of $LiFePO_4$ induces mouse TC1 lung cancer cells, no evidence suggests that $LiFePO_4$ impacts human A549 lung cancer cells. The Seahorse Assay indicated that $LiFePO_4$ represses oxygen consumption-related respiration in mitochondria of breast MDA-MB-231 cells while promoting glycolytic activity in cells. The TEM images suggested that the increase in mitochondria in $LiFePO_4$-treated breast cancer cells could be attributed to mitochondrial fission. Together, these findings reveal the potential of $LiFePO_4$ in promoting breast cancer cell growth and provide insight into mechanisms underlying the $LiFePO_4$-induced breast cancer cell growth by programming the cell energic metabolism.

Degradation of Residual Dyes from the Hydrolysis of PETE Plastic

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Plastic pollution remains a problem, with over 170 trillion pieces of plastic in the world's oceans. A process that can efficiently degrade PETE plastic is hydrolysis, where the PETE is broken into its Terephthalic Acid and Ethylene Glycol monomers, which are the fundamental chemical building blocks that form plastics. TPA serves a commercial purpose in paints, pharmaceuticals, and environmental industries. While this useful, oftentimes harmful dyes remain in the obtained TPA, undegraded by the hydrolysis process. Green PETE plastics were degraded under neutral-hydrolysis conditions for 2 hours, after which TPA was produced. It was found that the UV degradation of the remaining dyes within the obtained TPA in the presence of TiO2 could be performed in a timely manner, with all samples reaching near 100% degradation within 30 minutes. The process produced statistically significant results, showing that TiO2 has an important role in the kinetics of dye degradation, with a rate order of 1. In addition, the degradation proceeded the fastest in acidic conditions. Both of these processes can be easily industrialized, as TPA is naturally acidic and plastics contain TiO2 as a white additive. The research can lead to designing a concerted mechanism, where both plastic and dyes are degraded, yielding in a cost-effective, environmentally friendly process.

Louisiana

The Categorization of Kidney Cancer Using Machine Learning Based on lncRNA Expression

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Teacher: Cameron Hall, Caddo Parish Magnet High School

While only 1% of the human genome codes for proteins, the other 99% is not junk. Non-coding RNAs are an important factor in cellular function, controlling the transcription of genes, degradation of mRNAs, and other processes. Due to their many cellular functions, long non-coding RNAs (lncRNAs, >200 nt) influence a multitude of diseases and processes. Particularly, variation in expression of many lncRNAs has been found to be highly specific to various types of cancer. For certain cancer types, specific lncRNAs are up or down regulated predictably. The aberrant expression gives this category of RNA great potential as a biomarker to improve the accuracy of cancer diagnosis. Tools such as machine learning can be used to predict a class based on input data. To apply this idea to cancer diagnostics, I trained a logistic regression model to predict kidney cancer subtype based on lncRNA expression levels. I performed a Principal Component Analysis on lncRNA data obtained from TANRIC, an open resource RNA-seq database. When used to distinguish different types of kidney cancer, the model achieved an accuracy score of 92%. Machine learning models like this could replace current biopsy methods that can be inaccurate. This successful model provides promise for the use of lncRNAs in clinical diagnostic use once more research and data are collected by the scientific community.

The “Ideal Battery”: Testing Electrolytic Cells Under Various Conditions

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Teacher: Cameron Hall, Caddo Parish Magnet High School

This project is designed to test various electrolytic cells under different environmental conditions to test their efficiencies. An electrolytic cell proposes an alternative to nonrenewable batteries due to the hydrolysis of water. The ideal battery can pass a constant current through heat and humidity while maintaining a constant voltage. If electrolytic cells can use these conditions, further testing could be done to create a clean-energy battery. A controlled environment was built to create a humid and warm environment for both types of electrolytic cells. Through testing magnesium sulfate heptahydrate and potassium chloride at various voltages and environmental conditions, magnesium sulfate heptahydrate proved to maintain a semi-constant voltage and current under heat and humidity trials. Also, various voltages of a power source were tested and magnesium sulfate heptahydrate maintained a stronger current. In later testing, the 9V batteries were replaced with a small solar panel and the tests were repeated. The magnesium sulfate heptahydrate created a strong electrolytic cell and could be used to power these cells in the future. A potential error could be the size of the electrodes or the controlled environment.

The Production of an Anti-PCHD1 Monoclonal Antibody for the Purpose of Combating Hantavirus

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Mentor: Dr. Rohit K Jangra, LSUHS Ochsner

Hantaviruses, a group of RNA viruses, pose a significant threat to humans all around the world. Infection can cause severe consequences, including the fatal hantavirus pulmonary syndrome (HPS) and hemorrhagic fever with renal syndrome. In light of the lack of effective treatment options, this project focuses on developing an anti-PCDH1 monoclonal antibody to combat hantavirus infections.

The antibody is created through plasmid manipulation and Expi-CHO cell transfection. The transformation process involves introducing plasmids encoding the antibody's heavy and light chains into competent E. coli cells, followed by quality control measures. After successful transfection into Expi-CHO cells, a 10-day culturing period allows for antibody production. The purification process, using protein A sepharose beads, isolates the antibody from cellular components. Quality check methods including gel electrophoresis and ELISA assays confirm the antibody's production and specificity in binding to the PCDH1 receptor.

This anti-PCDH1 antibody presents a potential solution to disrupt hantavirus infections. Future steps involve testing its efficacy in a BSL3 lab and evaluating its antiviral activity in live animal models, marking a significant advancement in hantavirus treatment.

Navigating Demographic Disparities in Louisiana Women’s Health Using Machine Learning Within Geographic Analysis

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The issue of women's health in Louisiana is critical, given the state's extremely high maternal mortality rates. Women's health issues disproportionately impact Black and low-income women in our state, underscoring a persistent challenge in providing quality healthcare. By integrating datasets from the Louisiana Department of Health and other state and federal-level organizations, a geospatial model was made in ArcGIS, associating socioeconomic factors with infant mortality rate. Because infant mortality rate is a prominent health issue for Louisiana women, it was used as the primary determinant of women’s health for this research. Following the trend analysis between analysis fields, machine learning tools within the software were used to cluster parishes into regions of “High,” “Medium,” and “Low” threat to maternal health. The majority of the parishes labeled under “High” threat were located in the northeast region of the state. Their poverty rates, distance from maternal crisis care, and Medicare enrollment tended to be higher, while their income levels tended to be lower. Additionally, regions with a high Black population were typically labeled as “High” or “Medium” threat parishes. Ultimately, this model aims to highlight the urgency of addressing maternal health disparities and advocate for informed strategies in partnership with policymakers and healthcare providers to improve women's health outcomes in Louisiana.

Utilizing Machine Learning to Mitigate the Risk of Transfusion-Related Hemolytic Reactions

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The monocyte monolayer assay is a cellular assay, an in-vitro procedure that mimics extravascular hemolysis. The assay is used to predict the clinical significance of red blood cell antibodies in transfusion candidates with intent to determine whether the patient needs to receive the expensive, rare, antigen-negative blood to avoid an acute hemolytic transfusion reaction that could lead to death. The assay requires a highly trained technician to spend several hours over a microscope, evaluating a minimum of 3,200 monocytes on a glass slide in a cumbersome process of repetitive counting.

I employed machine learning to automate the identification and categorization of monocytes in slide images, presenting a significant improvement over the manual counting approach. The trained model can locate, identify, and categorize monocytes, separating them from the background and noise on the images acquired by an optical microscope camera. In the absence of a publicly accessible database containing these slide images for training the model, I acquired them at LifeShare Blood Center in Shreveport, Louisiana, and established an extensive public repository with the goal of serving as a comprehensive resource for automated analysis of monocytes.

Utilizing the trained model I implemented on a Raspberry Pi, blood bank technicians can optimize their monocyte monolayer workflow, resulting in time and effort savings and ultimately contributing to expedited and improved medical diagnoses. Performance evaluations demonstrate this approach can ease and accelerate the medical laboratory technician's repetitive, cumbersome, and error-prone counting process, and therefore contribute to the accuracy of diagnosis systems.

Maryland

Exploring Lipoprotein De-fish-encies As A Result of Genetic Mutations

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One in three people are affected by metabolic disorders including obesity, high cholesterol, and high blood pressure, leading to increased risk of stroke, diabetes, and heart disease. The study of lipoproteins, which are macromolecules that play a crucial role in lipid transport in vertebrates, is essential to unpacking these diseases further. Deficiencies in lipoprotein production are a significant factor in the development of metabolic disorders. Zebrafish are particularly valuable for studying metabolic disorders because of their optical clarity during larval stages. My research analyzes mutations that affect the yolk, where the fish store fats and proteins during embryonic and larval stages. To conduct a zebrafish mutant screen to investigate lipoprotein production, mutations were introduced across the zebrafish genome using chemical mutagenesis When zebrafish develop lipoprotein production disorders, the yolk sac becomes opaque, leading to a phenomenon known as "dark yolk". My research focuses on Mutants 17 and 22, two of over thirty dark yolk screen mutants. For Mutant 22, genome sequencing followed by CRISPR/Cas9 editing of

candidate genes is being used to find the target gene causing the dark yolk. Complementation crossing against mia2/ctage5 mutants revealed Mutant 17 has a mutation in the same gene. Research with other ctage5 mutants can help reveal more about the relationship between ctage5 and lipoprotein production. My research in lipoprotein production contributes to our understanding of how metabolic diseases are influenced by blood lipid levels and may contribute to efforts to mitigate their harmful effects.

Determining the Metamorphic Temperatures of Rocks in the Raspas Complex using Zirconium-in-Rutile Thermometry to Compare to Computer Models

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The Raspas Complex in Ecuador, estimated to be approximately 120+ Ma old, is a metamorphic fossil subduction zone with diverse rock types including eclogites. This study determines the precise temperature conditions under which this rock formed enabling comparative analysis with computer model predictions to assist with seismic-event information. Three rock samples were used, which contain rutile, a mineral with trace amounts of zirconium oxide which helps determine temperature conditions. Specifically, rutile in garnet inclusions provides a more accurate measure of temperature than rutile crystals found in the matrix of the rock. The location of approximately 40 rutiles in each sample was determined using a petrographic microscope and mapped using Adobe Illustrator. Utilizing an Electron Probe Microanalyzer (EPMA), oxide concentrations at each rutile location were determined. Once confirmed as rutile, Zirconium (Zr) parts per million (ppm) were calculated from $ZrO2$ concentrations. Using zirconium in Rutile thermometry techniques (Kohn, 2020), temperatures for the three samples were derived by averaging Zr concentration within each sample using the mean-max Zr content method following the approach of Penniston-Dorland et al. (2018). The temperature range spanned from 500°C to 650°C, with one sample exceeding 600°C, possibly influenced by sample location or sub-microscopic inclusions of zircon. The obtained temperature generally aligns with previous predictions of the Pressure-Temperature conditions of the Raspas Complex; however, computer models still predict cooler temperatures on average. This discrepancy may result from the omission of shear heating in computer models or the neglect of the effects of exhumation on temperatures recorded by rocks.

CisRF: A Novel Machine Learning Approach to Predict Context Dependent Impacts of Disease Associated Regulatory Elements on Gene Expression

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Genome Wide Association Studies have identified 560,000+ Single Nucleotide Polymorphisms (SNPs) associated with disease, most of which are not in protein-coding regions of the genome. However, the biological mechanism behind these non-coding genetic associations remains largely unknown. Uncovering these mechanisms requires understanding impacts of genetic variants on gene expression which are tissue and cell type dependent, but wet-lab experiments to measure these impacts are costly and time-consuming. To address this problem, I developed a computational method, CisRF, to enable fast and low-cost evaluation of context-dependent effects of non-coding SNPs on gene expression across diverse tissues and cell types. CisRF models gene expression as a function of activities of non-coding DNA regulatory

elements via Random Forests (RF), trained using public ENCODE data with 414 pairs of RNA-seq and DNase-seq samples. Using principal components and cross-validation to adaptively optimize model complexity, CisRF achieved higher prediction accuracy compared to a naive RF in 73% of genes. Upon applying CisRF to hypertension and height-associated non-coding SNPs, I evaluated how perturbations of SNP-containing regulatory elements change gene expression in 97 distinct tissues and cell lines. CisRF correctly predicted that heart ventricle samples had significantly larger gene expression changes than other tissues in hypertension related SNPs (two-sample t-test, p-value=0.0038), while myocyte samples had larger gene expression changes for height-related SNPs (p-value=0.00069). This demonstrates CisRF's ability to efficiently screen large numbers of contexts to identify potential mechanisms through which non-coding genetic variants influence phenotype, which was not possible with conventional wet-lab experiments.

FFTstack: Integrating Fourier Transform and Residual Learning for Arctic Sea Ice Forecasting

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Arctic sea ice plays integral roles in both polar and global environmental systems, notably ecosystems, communities, and economies. As sea ice continues to decline due to climate change, it has become imperative to accurately predict the future of sea ice extent (SIE). Using datasets of Arctic meteorological and SIE variables spanning 1979 to 2021, we propose architectures capable of processing multivariate time series and spatiotemporal data. Our proposed framework consists of ensembled stacked Fourier Transform signals (FFTstack) and Gradient Boosting models. In FFTstack, grid search iteratively detects the optimal combination of representative FFT signals, a process that improves upon current FFT implementations and deseasonalizers. An optimized Gradient Boosting Regressor is then trained on the residual of the FFTstack output. Through experiment, we found that the models trained on both multivariate and spatiotemporal time series data performed either similar to or better than models in existing research. In addition, we found that integration of FFTstack improves the performance of current multivariate time series models. We conclude that the high flexibility and performance of this methodology have promising applications in guiding future adaptation, resilience, and mitigation efforts in response to Arctic sea ice retreat.

D.I.V.A: Spatial Navigation for the Visually Impaired using Convolutional Neural Networks, Stereoscopy and Sensor Fusion

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Visual impairment remains a challenging issue in biomedical sciences with a need for universally effective and affordable solutions. Severe conditions like cataracts, glaucoma, macular degeneration, and complete blindness due to visual cortex damage continue to lack economic remedies. Current solutions such as the white cane and optical surgeries are restrictive in mobility, invasive, or costly. To address this, we propose D.I.V.A, a novel wearable device to assist the visually impaired in unfamiliar environments. The device utilizes a stereoscopic camera, RGB camera, gyroscope, custom PCB, proprietary computer vision software, and a novel PDMS-based microactuator grid. Through a custom U-net neural network trained

with 80 object classes, the device detects and classifies obstacles in the surrounding environment of the user via semantic segmentation. Furthermore, it communicates this information through a GUI-commanded personalized spatial audio system, in conjunction with indicative actuation of the tactile interface that represents the front-facing environment on the palm of the user. The proposed aid is affordable, costing approximately $270, making it accessible to individuals facing financial constraints. To statistically justify the proposed system and its performance, successful experiments were conducted in indoor environments to test the software accuracy, sensory input of the tactile interface, and viability of D.I.V.A in an unfamiliar path. The experimental results demonstrate that the proposed assistive device performs all its functions with high accuracy, allowing visually impaired people to feel safe and comfortable in an indoor environment. We envision this device significantly improving the lives of visually impaired individuals, especially those with limited access to expensive solutions.

Michigan

What's USP with Multiple Sclerosis?

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Multiple sclerosis (MS) is characterized by immune-mediated demyelination of nerve fibers, but its molecular mechanisms remain unclear. Here, we integrate bioinformatics analysis and experimental validation to investigate Ubiquitin-specific protease 33 (USP33) in MS. Using gene expression data from MS brain tissue, we identify USP33 as a significantly dysregulated gene in MS. Looking at USP33's molecular pathways, we see it implicated in the Ubiquitin-mediated proteolysis pathway and immune activation, linking it to MS pathogenesis. Immunohistochemical staining confirms USP33 overexpression in MS brain tissue and suggests its potential as a therapeutic target. Functional annotation reveals regulatory mechanisms governing USP33 expression, including transcription factors and RNAi. This approach demonstrates USP33's role in MS pathogenesis, offering insights for targeted therapies.

Biomimetic Airfoil Optimization to Supplement Flight Efficiency in Unmanned Aerial Vehicles

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Wing-based unmanned aerial vehicles (UAVs) are aircrafts designed to be operated remotely in critical areas for assessment mitigation and object identification. Traditionally, UAVs employ fixed airfoil systems, limiting their adaptability and efficiency, especially in dynamic flight conditions where Reynold's number is eminently high. More specifically, the rigid structure of the airfoil prevents efficient lift generation, rapidly depletes fuel during transition periods, faces premature stall during altitude changes, and are prone to vulnerabilities in maneuvering. This study suggests driving improvement in UAV performance through the introduction of avian features into the structure of the airfoil and air profile. Through rigorous analysis of avian exoskeletons, features, and supracoracoideus muscles, several individualized features were adapted and modeled through computer-aided design (CAD) software. The design included in this study incorporates serrated edges and vortex dividers, alula-inspired air profile extensions, morphing airfoil modules with servo and rotary systems, and a piston-based passive flight mechanism to increase flight efficiency and retrievability of military UAVs. The paper also delves into the discussion of feasibility of implementation and material considerations in a flying prototype. Additionally, Computational Fluid Dynamics (CFD) simulations, wind tunnel testing, and mathematical modeling were employed to assess the impact of these biomimetic features and demonstrate theoretical feasibility in subsonic, critical environments ranging in Reynold's number from 50,000 to 1,000,000. The integration of these various structural pieces promises a synergistic effect, resulting in an estimated 35% overall improvement in aerodynamic performance from current UAV standards.

KTV Transformer: A Novel Multi-scale Knowledge Transfer Vision Transformer for 3D Brain Vessel Segmentation

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A growing body of evidence in recent studies shows that small cerebrovascular abnormalities are the cause of many brain disorders. In order to facilitate the robust and precise 3D cerebrovascular extraction and quantification from in-vivo Magnetic Resonance Imaging (MRI) data, this paper presents a novel Multi-scale Knowledge Transfer Vision Transformer (i.e., KTV-Transformer) for 3D vessel segmentation. First, it uniquely integrates convolutional embeddings with Transformer in a U-net architecture, which simultaneously responds to local receptive fields with convolution layers and global contexts with transformer encoders in a multi-scale fashion. Therefore, it intrinsically enriches local vessel feature and simultaneously promotes global vessel connectivity and continuity for a more accurate and reliable segmentation. Furthermore, to enable using relatively low-resolution (LR) images to segment fine scale vessels, a novel knowledge transfer network is designed to explore the inter-dependencies of data and automatically transfer the knowledge gained from high-resolution (HR) data to the low-resolution handling network at multiple levels, including the multi-scale feature levels and the decision level, through an integration of multi-level loss functions. The modeling capability of fine-scale vessel data distribution, possessed by the HR image transformer network, can be transferred to the LR image transformer to enhance its knowledge for fine vessel segmentation. Based on the vessel segmentation results, quantitative metrics can be generated for computer-aided diagnosis of brain diseases and scientific discovery. Extensive experimental results on public image datasets have demonstrated that my proposed method outperforms all other state-of-the-art deep learning methods.

A Deep Learning Approach to Dementia Identification Using Clock Drawing Figures

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Dementia is the loss of cognitive functioning across multiple domains and impedes functions like memory, language skills, problem-solving and visual perception. Globally, dementia affects around 47 million people.

The clock drawing test (CDT) is a neuropsychometric clinical test used to assess a variety of cognitive functions. In Dementia, CDTs are interpreted both quantitatively and qualitatively and are widely used screening tools. However, human analysis of the clock drawing tests may leave room for misinterpretation errors. Unbiased testing in healthcare is cardinal for ensuring optimal patient prognosis, and supervised machine learning can be accordingly used for objective image analysis. Here, deep learning is used to objectively analyze and categorize CDTs as either dementia positive or negative.

We achieved good results and display that deep learning mechanisms are an effective way to identify dementia in patients. The model uses characteristics in the patient CDTs to diagnose individuals instead of interpreting them on a scoring system. This is useful as there are numerous ways to score CDTs and this method is consistent across all tests. It also provides insight into how dementia may alter parts of the brain involved with CDTs. With the ease of model development, this model could easily be transformed into more accessible options, like an online app.

Novel Integrated System for Segmentation and Analysis of Intracranial Arteries and Aneurysms Using Convolutional Neural Networks and Computational Fluid Dynamics

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Brain Aneurysms are a significant challenge for neurosurgeons due to the often-fatal consequences of their rupture. Therefore, it is crucial to develop methods that enable doctors to detect brain aneurysms

from Magnetic resonance angiography (MRA) images. Additionally, providing tools for assessing rupture risk will aid them in making informed decisions about surgical interventions. However, currently available tools do not adequately assist physicians in identifying and assessing aneurysm risks. This study proposes an AI model that segments brain MRA images to obtain both the artery and aneurysm masks. I have trained several state-of-the-art medical image segmentation models for this task. Using the Aneurysm mask, useful geometrical features can be extracted and analyzed using persistent homology to assist the neurosurgeon when performing surgery. For effective Computer Aided Engineering process, I start with converting these 3D images to Computer-Aided Design (CAD) models for blood flow pattern with final step of analysis using Computational Fluid Dynamics (CFD). I use the CFD simulations to investigate hemodynamic parameters such as blood flow and velocity. This modeling and simulation help to perform early prediction on the geometrical effects of hemodynamics. Preliminary results suggest that this novel approach can significantly enhance physicians' ability to assess aneurysm risks accurately and make informed decisions about surgical interventions. This study contributes to the advancement of neurosurgical diagnostics and paves the way for more effective and personalized treatment strategies for brain aneurysms.

Mississippi

BLASTing Away Viruses!

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The purpose of this experiment is to evaluate the effectiveness of vaccine predictions made by the WHO for Influenza outbreaks. This can be applied to real-world situations to enhance the efficiency of vaccination programs and improve public health preparedness. In this experiment, I was testing how often the vaccine is a good match each season, and how often the prediction fails. I hypothesized that there would be a 60-70% match for Influenza, hypothetically resulting in 30-40% of the population that would be infected even with the vaccine. To perform this experiment, first ensure your computer has a stable internet connection and create a table to record data. Then, to find antigenic data for Influenza, go to the Flu Activity & Surveillance webpage at The U.S. Centers for Disease Control and Prevention (CDC) website and find the most common influenza strains subtyped for the three most recent seasons as well as the strains in that season's influenza vaccine. Then, using the BLAST tool on the National Center for Biotechnology Information (NCBI) website, compare the sequences of each common strain with the vaccine strain using the hemagglutinin and neuraminidase proteins. From this experiment, it was found that my hypothesis was partially correct. The accuracy of the WHO's vaccine predictions do vary, and some predictions align well with the strains, with others not so much. It was found that overall, there was approximately a 50-60% match, hypothetically resulting in 40-50% of the population that received the vaccine to still be infected.

Modeling Lattice Fins as Flight Control Surfaces for a Precision Guided Landing of Reusable Rockets Continuation Study

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The proliferation of reusable rockets has driven expenses down and launch frequencies up completely reshaping the space exploration industry. A critical component of this sustainable technology are the Flight Control Surfaces (FCS) on reusable rockets in the form of lattice grid fins. Using computer-aided design, four novel lattice fin designs were produced and attached to a rocket booster. Each fin was oriented at varying angles of attack (AOA) to analyze the comprehensive behavior of the FCS.

Four models were created; Model 1 is the most advanced design currently operated by the industry and Models 1, 2, and 3 have never been tested. The force moment (torque) on each rocket model will be recorded to quantify the torque delivered to the rocket by each grid fin and AOA. Force coefficient plots were calculated using a Computational Fluid Dynamics (CFD) wind tunnel website simulation for an exhaustive analysis.

An FCS with a relatively higher force moment consistent over different AOA characterizes a superior design for rocketry. Model 3 outperformed every model including the industry's most advanced design, Model 1. Implementing these superior FCS on reusable rockets and precision guidance systems will save upwards of millions of dollars in expensive propellant and auxiliary launch expenditures. This research may also be applied to any fluid-born precision guided body as seen in defense projects. A more advanced FCS helps stimulate discovery on the final frontier, offers insights into further applications, all while supporting the United Nations Sustainable Development Goal 9 for industry, innovation, and infrastructure.

An Analysis of COVID-19 Social Vulnerability and Racial Disparity in the Mid-South: Model Prediction and Machine Learning

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Mentor: Junmin Wang, University of Memphis

Increasing research shows that COVID-19 has disproportionately impacted racial minorities and people with low socioeconomic status (SES). By using statistical methods and machine learning data analysis, my study predicted how the interactions between community-level social vulnerability and individual-level factors affected COVID-19 infection, hospitalization, and in-hospital mortality in the Mid-South's tri-states (Arkansas, Mississippi, and Tennessee). Community-level Social Vulnerability Index (SVI) was derived from the Centers for Disease Control and Prevention (CDC)'s 2020 SVI dataset and matched with patients' individual-level data by zip codes. Patients' demographics, COVID-19 testing results, hospitalization, and mortality statuses were retrospectively extracted from an electronic medical record system. Risk-adjusted multivariate logistic regression models were used to assess the associations between risk factors and COVID-19 outcomes. Bootstrapping machine learning methods were used to improve model predictions. My findings showed that people living in communities with vulnerable household composition and a high percentage of minority residents were more likely to get infected. Hispanics and Blacks living in communities with high SVIs also suffered the most from COVID-19 infection. No statistically significant differences were found from social vulnerability in predicting hospitalization, as age and race were the dominant predictors. Moreover, no statistically significant effects of race or social vulnerability on mortality were found. Bootstrapping-based machine learning offered similar results. My findings showed the racial disparity and community-level social determinants of COVID-19 infection. My study contributed to the existing literature by showing the interactive relationships between community-level social vulnerability and race affecting COVID-19 infection in the understudied Mid-South.

Divergent Survival Patterns in Boar Spermatozoa Linked to Oxidative Stress during Prolonged Storage

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Artificial insemination relies on viable semen, the maintenance of which in the swine industry is a challenge due to the gradual decline in sperm quality during chilled storage. Previous studies have demonstrated the existence of Good and Poor preservation survival semen exhibiting divergent decreased sperm motility during storage. Identification of intracellular mechanisms associated with semen quality during storage is paramount for the potential prediction of Good and Poor survival of semen. This study investigates the underlying biochemical factors contributing to this variability. Extended single semen doses of fertile boars (n=25) were analyzed daily using a Computer-Assisted Sperm Analyzer for sperm motility and morphology during seven-day storage at 16–18°C. On Day 7, semen samples exhibiting extremely high and low sperm motility were identified as Good and Poor, respectively. These samples were further analyzed using commercial-grade biochemical assay kits (free radicals or ROS, total antioxidant capacity or TAC, and thiobarbituric acid or MDA) to evaluate the oxidative stress level of spermatozoa on Day 0 and Day 7. Data were statistically assessed with ANOVA, followed by the pairwise t-test. $P<0.05$ indicated significance. On Day 0 of semen collection and extension, all samples had comparable sperm motility and normal morphology parameters ($P>0.05$), but they were significantly decreased on Day 7 (vs. Day 0). However, Good samples maintained higher values than Poor counterparts ($P<0.05$). They exhibited higher TAC and lower MDA and ROS than Poor samples on both days. Findings indicate that a higher TAC-to-MDA ratio may help identify good preservation survival boar semen.

Missouri

Revolutionizing Cancer Drug Discovery with DrugGen: Identifying a Novel Drug for DNA polymerase θ

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Mentor: Prof. Kamal Singh, University of Missouri

Homologous Recombination (HR) deficient cancers cause around 140,000 deaths yearly due to genetic changes, such as in BRCA1 and BRCA2 genes, which encode DNA repair enzymes. Mutations in these enzymes increase genomic instability, resulting in cancer growth. Chemotherapy is the standard treatment for HR-deficient cancers, but it causes severe side effects due to healthy cell death. Precision medicine offers a promising solution to the issue of specificity. Still, a significant percentage of patients fail to benefit from it due to the lack of FDA-approved drugs for targets overexpressed in their cancer. One such target is DNA Polymerase Theta (pol θ), a backup repair mechanism used by BRCA-deficient tumors. Pol θ is over-expressed in cancer cells and is an ideal drug target. Conventional drug development for this target would take significant resources and time. Computational approaches for drug development are promising to help in this chase of small-molecule inhibitors for targets. However, there is still no unified computational platform for identification of small-molecule inhibitors for precision medicine. Therefore, I developed DrugGen, an innovative approach that combines computational drug discovery utilities with a Graph-based Neural Network to identify novel inhibitors for use in precision medicine drug discovery. Using DrugGen, I identified a novel pol θ inhibitor with high potency, named SK-2. DrugGen is extensible for novel drug targets in precision medicine, and it can significantly reduce the cost and time required for drug development. Several targets in cancer still need to be explored, and DrugGen can help develop drugs for these targets.

Methamphetamine's Influence on the Blood-Brain Barrier: Dissecting Changes in Microvascular Endothelial Cell Structure and Function

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Mentor: Dr. Manikandan Panchatcharam, Louisiana State University Health Sciences Center – Shreveport

Background: Methamphetamine, a potent psychoactive substance, is known for its significant addictive potential and rapid impact on dopaminergic pathways in the central nervous system. Recent studies suggest it also exacerbates stroke outcomes by increasing the permeability of endothelial cells, affecting the blood-brain barrier. This study investigates the specific mechanisms behind this effect.

Hypothesis: We propose that high concentrations of methamphetamine influence junctional proteins in endothelial cells by amplifying oxidative stress, thereby impacting cellular permeability.

Methods: The study employed a multi-faceted approach. First, an Electrical Cell-Substrate Impedance Sensing (ECIS) machine assessed the permeability changes in Mouse Brain Microvascular Endothelial Cells (MBMEC) upon methamphetamine exposure. Next, we measured superoxide levels in MBMECs using High-Performance Liquid Chromatography (HPLC) to evaluate the production of reactive oxygen species (ROS) induced by methamphetamine. Finally, Western blot analyses for claudin-5, occludin, β-catenin, and superoxide dismutase (SOD2) were conducted to investigate the drug's effects on oxidative stress and junctional proteins.

Results: The ECIS data indicated increased permeability in MBMECs at methamphetamine concentrations of 250µM and 500µM. Additionally, methamphetamine at 250µM concentration significantly elevated superoxide levels and reduced SOD2 levels. A marked downregulation in the expression of occludin, claudin-5, and β-catenin was also observed at both 250µM and 500µM concentrations ($p<0.01$).

Conclusion: Methamphetamine decreases junctional protein levels in MBMECs in a concentration-dependent manner, partly due to increased oxidative stress. These findings elucidate the drug's detrimental impact on the blood-brain barrier and its potential role in exacerbating stroke, highlighting the need for further research into protective and therapeutic interventions.

Evaluating BMX-001 Efficacy: A SOD2 Mimetic Approach to Mitigate Myocardial Ischemia-Reperfusion Damage

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Mentor: Dr. Sumitra Miriyala, LSUHSC

Background: Myocardial ischemia-reperfusion (I/R) injury, a critical cardiac complication, is characterized by an excessive generation of reactive oxygen species (ROS) during heart reoxygenation. This leads to lipid peroxidation and subsequent cellular damage, primarily mediated by 4-Hydroxynonenal (4-HNE). The natural defense mechanism, like SOD2, a superoxide dismutase, is often insufficient against this ROS surge. This study evaluates the effectiveness of BMX-001 (MnTnBuOE-2-PyP5+), a SOD2 mimetic, in reducing oxidative stress in H9c2 cardiomyocytes subjected to hypoxia/reoxygenation (H/R) injury.

Methods: We used an in vitro model to simulate I/R injury in H9c2 cardiomyocytes. After 4 hours of oxygen deprivation and 24 hours of reoxygenation, cell viability was assessed using the Evans Blue exclusion method. Two concentrations of BMX-001 were tested, with 10 µL selected for optimal cardioprotection. The treatment's impact on intracellular superoxide levels was quantified using HPLC post-DHE treatment.

Results: H/R injury significantly increased intracellular and mitochondrial superoxide, as well as 4-HNE levels, indicating oxidative stress and lipid peroxidation ($p<0.05$). BMX-001 treatment resulted in a notable reduction in these oxidative markers ($p<0.01$). Furthermore, BMX-001 pre-treatment significantly mitigated H/R-induced cardiomyocyte apoptosis, improved mitochondrial function in terms of oxygen consumption, and decreased cardiolipin peroxidation and 4-HNE associated proteins ($p<0.05$).

Conclusion: This study reveals BMX-001's efficacy in diminishing oxidative stress markers in H9c2 cells during I/R conditions, highlighting its therapeutic potential in cardiovascular diseases driven by oxidative stress. BMX-001, as a SOD2 mimetic, demonstrates significant promise in enhancing cardiomyocyte resilience and treating heart diseases associated with oxidative stress.

Sticking To It: Using Multi-Walled Carbon Nanotubes as Possible Adsorbents for Sulfamethoxazole

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Sulfamethoxazole is a veterinary pharmaceutical that has been implemented into animal feed to improve chick growth, animal health, and meat production. However, sulfamethoxazole can't be fully metabolized (50-100%), and is usually excreted. This presents a problem as sulfamethoxazole is very water soluble and has shown high mobility in soil, which allows it to enter the environment with ease. Sulfamethoxazole has been found to be very toxic to aquatic organisms. Current waste water treatments are not capable of fully extracting the pharmaceutical from the water, so the compound can also be re-introduced in the environment through reclaimed water. The purpose of this study was to determine if multi-walled carbon nanotubes could be used as possible adsorbents for sulfamethoxazole. To conduct this study, batch reactors were prepared. Each batch reactor held 30 ml of a sulfamethoxazole solution at a concentration of 600 µg/L. The carbon nanotube concentration was .5% for the low treatment group and 2% for the high treatment group. In addition, a control treatment group which contained no nanotubes was prepared. All of the batch reactors were placed on an orbital shaker for mixing. At 0 hour, 30 minutes, 2 hours, and 24 hours of treatment, 1 mL samples were removed from each of the batch reactors. For the analysis of sulfamethoxazole concentration, the samples were analyzed using a high-performance liquid chromatograph (HPLC) with ultraviolet detection. It was discovered that the application of multi-walled CNT's was very effective in removing the sulfamethoxazole from the solution.

Efficiency of a 3D-Printed Pico-Hydroelectric Generation System Using a Fused Deposition Modeling Printer

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Several studies have shown that hydroelectric generation systems using an undershot water wheel can reach an efficiency of around 65%; however, making these generation systems out of Fused Deposition Modeling (FDM) polymers has yet to be accomplished. This paper aims to report if a 3D printed hydroelectric generation system produced on a very small, or pico-, scale is able to be compared to current-day systems made of more traditional materials. This will be tested by first creating a 3D model of all system components, including the water wheel, enclosure, and gearing. During the creation process of the 3D models, previous research done throughout the scientific community will guide the design to theoretically maximize efficiency. After the creation of the models, they will be printed out, assembled, and then tested. If efficiency is the same as systems made of traditional materials, 3D-printed FDM polymers could become a new material that is worthwhile to utilize in pico-hydroelectric generation systems. At the date of submission, several tests have been completed that show an average system efficiency from the tested flow rates range of upwards of 47.5%.

New England Northern

Blueberry-Born Nanovesicles as Potential Antioxidants for Treating Neurodegenerative Diseases

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Blueberries, recognized as "super-healthy" fruits, offer benefits like reducing oxidative stress and enhancing cognitive function, potentially protecting against neurodegenerative diseases. However, their high-value bioactives like polyphenolics face challenges in stability and brain delivery. This study explores blueberry-derived exosomes (BBDExo) as nanovesicles that might encapsulate these bioactives, offering improved stability and enhanced cellular uptake, thereby potentially increasing their effectiveness in neurological applications. The isolated exosome size was 82.7±6.4 nm and appeared as individual sphere-shaped morphology under scanning electron microscopy (SEM) analysis. 25 µg/mL exosomes quantified by total proteins promoted the best proliferation of brain endothelial bEND.3 and neuronal SH-SY5Y cells. Brain endothelial bEND.3 cellular uptake of fluorescence-labeled BBDExo significantly. Interleukin 8 (IL-8) secretion from inflammation-stimulated normal colon cells was significantly reduced by the BBDExo treatment ($p<0.05$). Overall, the isolated BBDExo improved the stability, brain delivery, and therapeutic efficacy of bioactives in brain cells via a naturally formed nanostructure. Demonstrating that BBDExo interacts with the targeting brain inflammatory cells and regulates anti-inflammatory responses would be a significant step forward in treating neurodegenerative diseases. The characterized exosomes with biomolecules may deliver therapeutic molecules in the brain and target neural cells, leading to improving efficacy in the treatment of neurodegenerative diseases.

The Handheld Plant Spectroscope

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Plants make up over 80% of the Earth's biomass. Monitoring their health status is important to understand environmental changes as well as an extremely useful tool in the world of agriculture. Plant health can be correlated to the concentration of chlorophyll which determines the absorption spectrum of plants. The spectral characteristic of vegetation can be characterized with the Normalized Difference Vegetation Index (NDVI). The NDVI measures the contrast between light reflected in the red and in the infrared, resulting in an index value in the range between -1 and 1. This device is already well known and accurate; however it is very costly. The NDVI index is typically considered for multi-spectral imaging devices. The device that has been designed is The Handheld Plant Spectroscope. This device is essentially an extremely low cost NDVI device that is handheld, works in close proximity to plants, allows active illumination using spectral selectivity achieved via a set of Arduino software and based red, green, blue, and infrared LED lights with specific wavelength and is equipped with a TSL2591 Light Sensor with large dynamic range to collect data.

The function of the device was tested by monitoring sage plants which received different amounts of water. The results showed that the device readings correlate qualitatively with visible differences in the health status of the plants. The entire device costs less than 50 USD, making it extremely cost efficient in comparison to other devices that are already established in the monitoring of plant health.

The Glucose Metabolism of ADHD: MicroRNA SNPs Impact Glucose Transporter 3 Expression

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ADHD affects millions globally, with symptoms like inattention and hyperactivity significantly impacting quality of life. Despite this, current treatment medications can have substantial side effects, are ineffective long-term, and are inaccessible to many due to shortage.

This study aimed to address this by developing a sugar intake-based ADHD symptom management theory. Although most ADHD research focuses on neurotransmitter balance, this study focused on the impact of microRNA (miRNA) variants on Glucose Transporter 3 (GLUT3), a membrane protein that plays a central role in neuronal glucose metabolism.
MiRNA single nucleotide polymorphisms (SNPs) that target GLUT3 mRNA and their consequential effects on GLUT3 function were computationally scrutinized with TargetScan and RNA22. SNP rs769854452 in hsa-miR-103a-3p increased miRNA binding function ($p<0.05$), suggesting a decrease in GLUT3 expression, while SNP rs901180005 in hsa-miR-107 led to complete target loss, suggesting an increase in GLUT3 expression.

SH-SY5Y neurons were transfected with the identified miRNA variants: rs769854452 (hsa-miR-103a-3p) and rs901180005 (hsa-miR-107). Analysis via quantitative RT-PCR for mRNA expression and western blot for protein synthesis confirmed that transfection with rs901180005 (hsa-miR-107) led to a significant increase in GLUT3 mRNA expression ($p<0.05$) and protein synthesis ($p<0.05$). GLUT3 protein expression

(ELISA-analyzed) was increased in the blood of ADHD patients who had micronutrient supplement intervention (and improved symptoms) compared to those that had no intervention. SNPs rs901180005 could inform sugar intake as management for ADHD symptoms. Future research includes further confirming the expression of miRNA SNPs and GLUT3 in ADHD patients.

Effects of Bisphenol A and Bisphenol S Exposure on Models for Body Systems

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Bisphenol A (BPA) is a common plasticizer used in manufacturing that negatively impacts human health. Bisphenol S (BPS) is a common substitute for BPA, but its structural similarity to estrogen sparks concern that it is harmful to the reproductive system, stem cell regeneration, and microbiome health. Past studies in *Caenorhabditis elegans* found that BPA and BPS exposure reduces fertility and affects DNA double-stranded break repair (DSBR) during meiosis. Mouse studies also showed that BPA exposure decreases microbiome diversity and hampers sperm cell development from stem cells. In this study, the effect of BPA and BPS exposure on *C. elegans* fertility and the expression of DSBR genes *rad*-54 and *atl*-1 was observed over multiple generations. No consistent significant effects on fertility were observed, but expression of both genes decreased in the exposed generation and their offspring. Modeling stem cell growth, the regeneration of brown planaria exposed to BPA and BPS was tracked, finding that low BPA concentrations slowed regeneration. Concentrations of BPA above 10 μM caused the planaria to disintegrate, but BPS did not have a significant impact on them. The effect of BPA and BPS exposure on the growth of *Escherichia coli* and *Saccharomyces cerevisiae*, both found in the microbiome, was also tracked. Exposure nonlethally affected microbial growth in a disk diffusion test, but BPS slowed growth of *E. coli* in liquid media. Based on these results, BPA and BPS have distinct effects on these models for reproduction, microbiome health, and stem cell regeneration, supporting further investigation.

An Image Segmentation Algorithm Targets Marine Trash for ROV Retrieval

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Oceanic debris, predominantly plastic, makes up 88% of the ocean's surface, inflicting catastrophic damage on marine ecosystems and threatening aquatic life through entanglement, strangulation, and starvation. Tackling this crisis is complex because of the wide-ranging distribution of waste by ocean currents to remote and deep-sea locations. Remotely operated vehicles (ROVs) are a solution, capable of withstanding extreme underwater environments. In this study, I developed a ROV prototype that uses a deep learning model to discern and identify components of images captured by an ROV. I utilized image segmentation, a process that groups or "masks" all pixels associated with a specific object in the image, to recognize and delineate image components (trash, animal, plant, ROV). My model, a convolutional neural network employing U-Net architecture, formulated feature maps and class predictions for each object within the images. The ROV prototype featured a Raspberry Pi and VEMONT Sports Camera, testing the model's efficacy in a mockup of an underwater environment. To evaluate the model, I compared the overlap of model-produced object masks and reference masks, calculating the Dice Similarity Coefficient (DSC) for each object class (trash = 0.81 ± 0.38, animal = 0.85 ± 0.35, plant = 0.88 ± 0.31, ROV = 0.86 ± 0.29, overall

average = 0.84 ± 0.36). My model's consistent categorization of image components makes it an accurate and effective tool for ROVs to identify previously inaccessible ocean trash for removal. This study lays a robust foundation for future research and additional applications.

New England Southern

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

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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 efficiencies of the three stop codons in terminating protein translation. Interestingly, I found that all three stop codons were "leaky" albeit at low levels and could be subject to termination readthrough. I identified the stop codon UGA (or TGA in DNA), when flanked with six virus-derived downstream nucleotides, was particularly amenable to chemical modulation in its readthrough propensity. Based on these findings, I constructed a new two-component gene switch that consisted of a nine-nucleotide, TGA-comprised DNA effector and a chemical inducer. 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.

Developing a Python-based Synthetic Aperture Radar Visualization System for Flood Mapping

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As we enter an era where natural disasters are increasing in frequency and intensity globally, the need for advanced disaster response technologies has never been more pressing. Floods, in particular, pose a formidable threat to communities and infrastructure worldwide, demanding effective and comprehensive response systems.

Remote sensing plays a crucial role in disaster response and has become an indispensable tool for scientists and decision makers alike. Synthetic Aperture Radar (SAR), an effective and rapidly developing technique, has traditionally relied solely on satellites for environmental monitoring. However, the unconventional approach of using an unmanned aerial vehicle (UAV)-based SAR system adds flexibility, unparalleled resolution, and potential for detailed disaster tracking.

Our system aims to pioneer new approaches to SAR-based remote sensing by creating a high-quality and low-computational-cost UAV-based SAR visualization system. Our software, programmed from scratch and fully based in Python, showcases effective approaches to SAR visualization using an integration of live UAV-based scans with geospatial satellite imagery for flood disaster response. Our project details the development of our SAR visualization system and our findings on the most effective approaches.

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

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The precise and accurate leukemia detection in current clinical practice remains challenging due to limitations in cost, time, and medical experience. To address this issue, this research develops ALLocate, the first integrated low-cost automatic artificial intelligence system for the real-time localization and classification of acute myeloid leukemia in bone marrow smears. ALLocate consists of an automatic microscope scanner system, an image sampling system, and a deep learning-based detection system. The automatic microscope scanner system uses 3D-printed pieces controlled by stepper motors and a RAMPS control board. For image sampling, 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%. When ALLocate was applied to a marrow smear, its leukemia detection results are similar to the results from a doctor, but ALLocate is much faster. This is the first report to integrate a deep learning system with a low-cost microscope automatic scanner system for leukemia detection. ALLocate can significantly improve the efficiency of leukemia detection from the marrow smears, especially in underserved communities, making healthcare more accessible to all.

Using Immune Footprints in a Novel Deep Learning Model to Detect Human Diseases

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In response to diseases and regardless of their characteristics, humans have developed an all-encompassing defense mechanism known as the immune system, where antibodies are a key player. For antibodies to be effective, they must bind to the surfaces of disease-related antigens with highly variable shapes, doing so through recombination processes that make each antibody unique. This uniqueness allows for a correlation to be established from an antibody to its corresponding disease. While there have been previous attempts to correlate diseases using feature-based machine learning, the direct use of amino acid sequences in a deep learning model remains to be explored. Here, we propose a language modeling-based approach for classifying disease-specific antibodies against a healthy control set. Using the pre-trained ProtBERT-BFD model from Rostlab, we were able to generate an embedding vector with 1024

values for each amino acid in an antibody sequence. These values were then averaged across every amino acid to obtain a single “sentence-embedding vector” that was passed to a feedforward neural network of progressively smaller layers. The final output consisted of probability matches for each disease, with the highest probability becoming the predicted class. This multi-class model was then implemented in antibodies associated with COVID-19, HIV, influenza, Dengue fever, CLL, and a healthy control, achieving an overall accuracy of 90.50%. We believe this high accuracy demonstrates the potential for a rapid, multi-disease diagnosis method supporting hundreds of diseases, carrying with it immense ramifications for the future of medical testing.

New Jersey Northern

Reducing Per-and Polyfluoroalkyl Substances (PFAS) Water Contamination With Mycorrhizal Hydroponics Plants

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Per- and polyfluoroalkyl substances (PFAS), known as “forever chemicals,” have carcinogenic effects and cause the deaths of 382,000 Americans every year. Over 600,000 military personnel are annually served water with unsafe levels of PFAS due to contamination by aqueous film forming foam (AFFF), a PFAS-containing firefighting foam used by the military. Current methods to purify PFAS-contaminated water can cost millions of dollars and require existing infrastructure, making them difficult to implement in lower-income and rural areas without industrial treatment plants. Hydroponics plants colonized by beneficial mycorrhizal fungi present an affordable and sustainable solution to purifying PFAS-contaminated water, particularly at government stormwater detention ponds. In this study, mycorrhizal-inoculated basil and lettuce plants were cultivated in deep water culture (DWC) systems under controlled conditions. PFAS was added to the systems and an LC/QQQ-MS instrument was used to measure PFAS concentrations in samples taken over 72 hours. Results showed that mycorrhizal plants removed 71.1% of PFAS in a water system compared to 59.9% by non-mycorrhizal plants, and t-test (p=0.05) was used to prove statistical significance. Further analysis revealed a direct relationship between plant root-length and PFAS purification as well as phytoremediation being successfully modeled by second-order kinetics. No significant difference was observed between uptake of short-chain and long-chain PFAS, indicating another advantage of phytoremediation over traditional filtration systems. This study provided a proof-of-concept of the effectiveness of mycorrhizal hydroponics plants in reducing PFAS contamination in water systems, presenting applications as an inexpensive and large-scale purification system.

Building a Neural Network: Predicting Mice Behaviors from rCPT Activity

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Machine learning and artificial intelligence have truly become some of the most groundbreaking technologies of modern time. Particularly, in the field of behavioral neuroscience, deep learning can be applied to the quantification of animal behaviors, which can unveil brain function in major physiological conditions. In this study, an advanced training platform, SLEAP (Social LEAP Estimates Animal Pose), was utilized to develop a neural network capable of tracking animal body part positions and predicting the behavioral mechanisms of rodents performing a continuous performance test (rCPT). The rCPT paradigm requires experimental mice to accurately discriminate and respond to brief presentations of nontarget and target stimuli in order to earn a condensed milk reward. This study analyzed data from the rCPT activity of wild-type mice and mice lacking forebrain acetylcholine expression (that have deficits in attentional function). The model was developed using a bottom-up approach, in which select mice body parts were first labeled from overhead videos in order to train an artificial neural network. Thereafter, the modified network was able to accurately associate the marker labels with their corresponding animals. Learning classification algorithms were then run to quantify the specific mice behavior, which supported the association between mice position and attention deficit in the rCPT. Thus, the neural network developed in this experiment can be applied to mice models of diverse neurological impairments. Ultimately, it can be further refined to test novel drug treatments in preclinical trials based on models of those behavioral conditions.

Computational Drug Discovery for α-synuclein Inhibition in Parkinson's Disease Neurodegeneration

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Parkinson's disease (PD) is a neurodegenerative disorder that leads to neuronal damage mainly because of the accumulation of misfolded alpha-synuclein proteins. This study uses a ligand docking approach using Schrödinger Maestro to identify potential compounds with the highest potential to inhibit alpha-synuclein aggregation. A diverse set of small molecules and peptides, found in literature to be known to have some effect on PD, were docked to predict their interactions with alpha-synuclein. Before docking trials began, it was hypothesized that Rifampicin would be a powerful candidate, which was supported by its molecular properties. Next, site analysis pinpointed the most promising binding site on alpha-synuclein, enhancing the accuracy of subsequent trials. Finally, the molecular docking simulations and compounds like Lacmoid, Rosmarinic Acid, and Synuclean-D exhibited the strongest docking scores, while molecules like Rifampicin, which had been hypothesized to be most effective, displayed no results. The data generated from this molecular docking study opens up potential therapeutic treatments for PD, and can guide future experiments *in vitro* to develop a cure for the neuronal damage related symptoms of PD.

SnNotch: Developing a Customizable Cell-Based Cancer Screening System for CAR Macrophage Therapy Applications

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Cancer is characterized by abnormal cell growth and is a leading cause of death worldwide. Traditional treatment options include surgery and chemotherapy, but the treatment success rate remains low for solid tumors. Recently developed Chimeric Antigen Receptor (CAR) T cell therapy engineers a patient's own T-cells to fight cancer cells. Current CAR-T cells exhibit limited ability to reach the tumor environment, while macrophages can easily submerge into the cancer microenvironment. SnNotch receptors are bioengineered cell-surface receptors that senses a target antigen and an immune response against cancer cells. In this study, SnNotch receptors were designed, transfused into monocytes and macrophages, and co-cultured with leukemia and kidney cancer cells. The goal of the study was to engineer the SnNotch macrophages to recognize tumor cells with both the CD19 and eGFP antigens. Signaling efficiency was determined by flow cytometry and immunofluorescence microscopy. Results show that 86% and 76% of SnNotch macrophages transmit antigen signal when co-cultured with kidney cancer and leukemia cells respectively. Fluorescent microscopy data reveals that monocytes signal more efficiently in solid tumors while macrophages signal more efficiently in liquid tumors. In this study, a novel, customizable SnNotch receptor was engineered for SnNotch CAR Macrophage Therapy. For future research, target antigens can be replaced with other immunological diseases targets such as multiple sclerosis and systemic lupus erythematosus. This research increases the efficacy of CAR macrophage therapies and advances recent cancer therapies by providing customizable cellular therapies to efficiently and accurately target cancer cells.

SNAKE - Smart Navigational Adaptive Kinematic Exploration: An effective locomotion of Multi-Terrain Pneumatic Muscle-Driven Modular Soft Robot

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Amphibious robots hold significant promise in scientific, commercial, and military applications, particularly in environments that are hazardous for humans. In this research, a modular amphibious soft snake robot was designed to navigate diverse terrains, utilizing a unified propulsion system for underwater swimming and terrestrial crawling. The robot's locomotion lies in a spring-reinforced pneumatic artificial muscle, generating a sinusoidal wave-like motion for efficient movement on both land and water. A unique pneumatic system consisting of six air chambers has been developed to independently regulate the traveling-wave undulation gait, ensuring seamless control regardless of the number of modules in the robotic system. Inspired by hierarchical hexagonal snake scale patterns, various 3D-printed silicone skins on the ventral side were employed to explore the directional efficiency of the robot's locomotion. Extensive experiments showcase the robot's versatility in crawling on diverse surfaces, such as sand, wood, gravel, concrete, and grass, while successfully navigating obstacles. Additional experiments also demonstrate the robot's maneuverability in swimming and hovering on water bodies, including an indoor pool and an artificial pond. The robot has been rigorously tested to traverse through pipes of different materials and dimensions. At a maximum actuation pressure of 206 kPa (30 psi), the robot achieved impressive speeds of up to 56 cm/s while crawling and 34 cm/s while swimming. The robot's efficient maneuverability through constrained environments, mimicking the movements of biological snakes on both land and water, opens possibilities for deployment in diverse applications, ranging from search and rescue operations to ecological surveys.

New Jersey Southern

Assessing Airborne Bacteria Abundance in Sea Foam Aerosol

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Foams, a natural phenomenon along aquatic shores, are produced by the agitation of particles in water. Foams can accommodate many types of microorganisms, and past research shows they can transfer harmful algal toxins into the atmosphere. The objective of this study was to observe the ability of foams to transmit residing bacterial microorganisms to aerosols. Study sites included five Barnegat Bay and Atlantic Ocean beaches along coastal New Jersey. Bacterial composition and concentrations in foams, foam aerosols, residing waters, and coastal air samples were analyzed. Water and foam samples were collected in sterile Whirl-Pak bags, swabbed, and transferred to a Luria Broth agar medium. To quantify bacteria in foam aerosols and coastal air samples, petri dishes were passively cultured by exposing them to volatilizing foams and atmospheric conditions. The results of this study found that foams had significantly higher bacterial concentrations compared to their counterpart waters, atmospheres, and aerosols ($p<0.01$). A positive relationship between bacteria in foams and their aerosols was also found; as bacterial concentrations of foams increased, bacteria in their resulting aerosols also increased ($R^2=0.5996$). The findings of this research unearth potential threats to the safety of coastal areas; foams and their aerosols can introduce many health risks to not just swimmers, but also to surrounding coastal communities and beachgoers through the transmission of airborne bacteria.

Role of 5-HTP Mediated Serotonergic Activity in Operantly Conditioned Memory Consolidation for *D. tigrina*

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Alzheimer's Disease (AD) is a progressive neurodegenerative disease that begins with mild memory loss and accumulates to severe dementia. The scope of research for AD has become increasingly narrow, now mostly focusing on investigating amyloid beta and tau. However, all this research on these two proteins have yielded few, if any, effective treatments for dementia. On the other hand, a relatively-unexplored molecule in this field, serotonin, seems to have some interesting implications in relation to the central nervous system (CNS). Recent research has revealed a connection between the hippocampus, which is involved in both AD and memory, and serotonin. Furthermore, my research on *D. tigrina* from previous years revealed a connection between serotonin and increased regeneration of the CNS – a function the human CNS lacks, leading to increased severity of AD. Therefore, serotonin's role in memory retention was quantified in this study. This was done using 5-HTP, the precursor to serotonin, and *D. tigrina*, a regenerating flatworm with a homologous CNS to humans. Half of the organisms were treated with liquid 5-HTP while the other half were the control. All organisms were operantly conditioned with a 3D printed Y-maze. The left side received light stimulus as positive punishment and the right side received beef liver as a positive reinforcement. Initial biases were taken without conditions and experimentation utilized a double-blind procedure. Conditioning was done for five days and Testing (memory retention) was done for five days following. This was repeated for Re-Conditioning and Re-Testing to quantify recall ability.

Employing Woodpecker Cranial Adaptations in a Novel Helmet Design for Increased Impact Protection

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Helmets are designed to protect against severe Traumatic Brain Injury (TBI). TBI can be prevented through impact force dissipation over a larger surface area, cranial deceleration over a lengthened period, and energy absorption through compression. Evolutionary implementation of these protective measures is seen in woodpeckers. Their beak, hyoid bone and tongue, and cranial bone structures work together and apply these processes to stop them from suffering TBI. These structures were used as the basis for the novel helmet concept which was then developed into a helmet prototype and tested against a consumer-grade helmet. It was hypothesized that the novel helmet would better protect the analog head from drop test impact forces than the conventional helmet would. Experimentation and subsequent data analysis supported the hypothesis, as the helmets were able to withstand and distribute a total of approximately 82 joules and 69 joules respectively, while still protecting the analog head. To further look into the applications of this helmet, a cost analysis was performed. It revealed that the novel helmet is estimated to be $2.45 cheaper for consumers than the consumer-grade helmet that it was tested against. Overall, this new type of design has a large variety of potential applications; these include incorporation into protective wear (helmets, body armor, shields, etc.), shock absorbing systems in vehicles and other types of machinery (cushions, dampers, bumpers, vehicle armor, etc.), and various other impact protection apparatuses.

Classical and Modern Control Theory for Rotor Sail Active Seakeeping

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90% of goods move by cargo ships, contributing to 3% of climate change emissions, 7.6 million childhood asthma cases, and 150,000 premature deaths annually. There is a need for climate change technology that works within existing political and economic structures, addressing externalities through a profit incentive. Rotor sail active seakeeping is a novel concept, and possible solution. This is the third phase in the development of the Active Vortex Scrubber Sail (AVSS), a three-in-one rotor sail with a centrifugal exhaust scrubber and active seakeeping. The goal was to determine which control system architecture best optimizes rotor sail seakeeping capability by reducing cargo ship roll, torque demands, and time to reach a stable minimal roll angle. PD and MPC control system architectures were compared using a mathematical model of cargo ship roll in MATLAB Simulink to gain new insight into rotor sail seakeeping capabilities. With both control systems, the rotor sail performed as an effective seakeeping device for small initial displacements. Both controllers reduced settling time in comparison to open loop, on average by 35%. Multipurpose devices are especially important on cargo ships, where space efficiency is prized. Beyond reducing climate change and illness, the AVSS investment pays for itself in under a year, while improving IMO emissions compliance, reducing risk of parametric rolling, and expanding the vessel's operating envelope and efficiency. Scaling to our global cargo fleet could mean a reduction of 93 million tonnes of CO_2, 1900 kilotonnes of nitrogen oxides, and 160 kilotonnes of particulate matter.

Novel Quantum Materials for Low Power Electronics

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Global energy consumption is increasing rapidly due to the proliferation of electronic devices, causing sustainability concerns, thereby requiring the use of new semiconductor materials. The quantum material Vanadium Dioxide (VO_2) is a prime candidate, as it undergoes a sharp insulator-to-metal phase transition (IMT) near room temperature (67ºC) and can act as a switch. The IMT can be optimized by electron doping using tungsten (W 6+). Currently, there are few models for determining the properties of this alloy material, given its complex electronic properties. Further, characterization of materials containing low dopant concentrations is challenging. In this study, linear models were developed based on experimental data collected from literature review to define the relationships between composition (dopant atom-percent concentration, ionic radius) and IMT properties (transition temperature, threshold voltage, activation energy). The linear models demonstrate that transition temperature and threshold voltage reduce as W concentration increases (~21K/at. % and ~19.6V/at. % respectively). These models were compared with impurity conduction theory and were found to agree at doping concentrations <1.8 at. %. Threshold voltage for IMT displays a similar trend as IMT temperature, suggesting that their mechanisms are related. Rutherford Backscattering Spectroscopy (RBS) was simulated using SimNRA and was determined to be a powerful method for characterizing the concentration of tungsten doped VO_2 thin films. The models predict that power consumption per device could reduce as much as 76%. The results from this study have established a quantitative relationship between impurity doping, transition temperature, and threshold voltage reduction to design low power electronics.

New York-Long Island

Utilizing Deep Learning to Facilitate Diagnosis of Look-Alike Leukemia Subtypes

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B-cell acute lymphoblastic leukemia (B-ALL) and acute myeloid leukemia (AML) are the 2 most common leukemias. The American Cancer Society estimates that there will be 59,610 leukemia cases and 23,710 deaths in 2023. Early detection of leukemia subtypes is critical in prescribing effective treatment strategies to maximize survival rates. Past studies using machine learning (ML) for diagnosing leukemia have achieved significant results, but very few studies were extended to cover the detection of specific leukemia subtypes. B-ALL and AML subtypes are difficult to distinguish because they have similar morphology. The objective of this study is to develop a novel dual-input model to distinguish subtypes of B-ALL and AML. Transfer learning will be utilized, and different classification algorithms: Fully-connected (FC), FC + Batch Normalization (BN), Global average pooling (GAP) will be tested on top of 3 CNNs (VGG16, DenseNet201, InceptionResNetv2). Image segmentation will identify malignant cells, and data augmentation will apply transformations to increase the number of training samples. The model's hyperparameters will be finetuned while callbacks track loss and mitigate overfitting. Of all CNNs tested, DenseNet201 with GAP achieved optimal test accuracy of 96.62% with an AUC score of 0.9989. Performance of the model will be validated using k-fold cross-validation. An app called LST Detector will be developed for public use and to create a community-supported repository of blood smear images for the model to undergo further training. This model is the first to successfully identify all morphologically similar subtypes of B-ALL and AML leukemias.

Fibroblastic Reticular Cells Modulate Tumor Microenvironment of Chronic Lymphocytic Leukemia (CLL)

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In patients with Chronic Lymphocytic Leukemia (CLL), there is an overgrowth of leukemic B-lymphocytes. This proliferation of B-cells requires inputs from the external microenvironment, which provides soluble molecules as well as physical interaction necessary for survival and proliferation. Studies have shown that the lymph nodes are one of such microenvironments. However, the specific interaction between lymph nodes and leukemic B-cell has not been elucidated. This study examines how fibroblastic reticular cells (FRCs) from the lymph nodes, and IL4 secreted by T-cells affect the proliferation and signaling of leukemic B cells.

When leukemic B cells were co-cultured with FRCs, there was a significant increase in the number of leukemic B cells. Moreover, the expression of CLECL1 surface protein is further increased on B-cells. Using recombinant CLECL1 protein, it was demonstrated that IL4 cytokine production increases in both naive T-cells and Th2 cells. In the presence of IL4, the level of proliferation of CLL B-cells is amplified. IL4 can also increase the expression of lymphotoxin (a cytokine) in B-cells and the lymphotoxin receptor on FRC. The expression of lymphotoxin is repressed in the presence of FRC. The expression of lymphotoxin in B-cells correlates with high levels of the adipocytokine CXCL13 by FRC. High level of CXCL13 subsequently correlates with reduced expression of CXCR5, which is required for B-cell migration and localization to the FRCs and is believed to play an important role in CLL cell proliferation. This study demonstrates that interactions with FRCs and IL4 is essential and necessary for CLL progression.

The Effect of Food Deprivation on the Memory of *Drosophila melanogaster* Larvae

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This study investigated the effects of food deprivation on the memory of *Drosophila melanogaster*. A memory assay was conducted on two groups of *Drosophila*, where the larvae were rewarded in the presence of either the scent N-amyl acetate (AM) or 1-octanol (OCT), and then tested to see which scent they would travel to when the reward was no longer present. The groups were then either food-deprived or given standard food, and the testing portion of the assay was repeated. Using the number of larvae recorded on each side of the testing plates, the groups' preference scores and learning index values were calculated. In the first testing assay, the groups had a positive learning index value, demonstrating that the larvae showed appetitive learning and traveled to the scent at which they were rewarded. In the second testing assay, the standardly fed groups had a negative learning index value, meaning the larvae traveled to the opposite scent than where they were rewarded, showing aversive learning. The food-deprived groups had a positive learning index value, but since it was closer to 0 than before food deprivation, they did not show as much learning as they did before food deprivation. The results for the first assay were expected however, the standardly fed and food-deprived larvae had unexpected results which may have occurred because the larvae had to rely on their long-term memory.

Using an Inexpensive Night Vision Camera as a Detector in NIR Spectroscopy

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Near Infrared (NIR) Spectroscopy is a technique that measures wavelengths from 780 nm to 2500 nm to determine the chemical composition of a sample, making it useful in various applications, from detecting

adulteration in food products to determining fruit ripeness. Recent efforts have aimed to increase the accessibility of spectrometers to consumers by lowering the cost of spectrometers by utilizing digital cameras as detectors in visible range spectrometers. This study investigated the potential use of common night vision cameras as detectors in NIR spectrometers. The design utilized an SQ13 mini camera as a detector to take the spectra of fluorescent, tungsten, and neon lamps. Initial measurements used to calibrate and determine the resolution of the spectrometer were done without any covering to block outside. Using the program ImageJ, the spectra was successfully extracted from the image, calibrated to wavelength, and calculated its full width at half maximum (FWHM) - the width of the peaks at half the height of the peak - to determine the spectrometer's resolution. A base/container for the spectrometer was later designed to secure the optical parts and block outside light for more accurate measurements. Calibrating the spectrometer was again, its resolution was calculated to have a FWHM of 6.767 nm. While this project demonstrates that a common $20 night vision camera can be used to measure a spectra with low resolution, future studies are needed to improve the design and to test its ability to measure chemical samples.

The Enhancement of a Novel 3D-Printed Electrodialysis Device through the Implementation and Optimization of Spacer Designs

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The ocean can serve as a massive drinking water source. Common methods of seawater desalination tend to be cost and energy intensive. Electrodialysis is a low-cost and energy-efficient desalination process involving ion movement driven by electric charge. For electrodialysis, the flow of water is critical to effectiveness. To address this, spacers can be introduced that create pathways for fluid movement and turbulence. The purpose of this study was to examine three spacers - tortuous pathway, cubic, and column - in comparison to a spacer-less control in order to improve fluid turbulence and compare their impacts on desalination performance. The electrodialysis module was 3D-printed, such that it was leak-proof and spacers could easily be swapped. For each design, salinity change and Reynolds number were determined. The control and the tortuous pathway, cubic, and column spacers provided average salinity changes of 5.15+/-1.03 ppt, 12.57+/-1.58 ppt, 8.98+/-1.96 ppt, 8.31+/-1.40 ppt, respectively. Additionally, the control and the tortuous pathway, cubic, and column spacers had Reynolds numbers of 3247, 9055, 4895, 4858. This demonstrated a direct relationship between average salinity change and Reynolds number, indicating that increasing fluid turbulence improves desalination. Of the spacers, the tortuous pathway was found to be the most effective, significantly improving desalination compared to the control ($p<0.05$). This is due to its design creating the greatest fluid turbulence. Overall, the creation of a novel 3D-printed electrodialysis design incorporating different spacer configurations was found to be a promising technology.

New York-Metro

Nitrogen Dioxide (NO_2) Emissions from Gas Stoves and Ovens in New York City Apartments

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Indoor air pollution released by kitchen ranges during cooking is an understudied public health issue. This study aimed to quantify residential air pollution from kitchen ranges in New York City apartments. Indoor nitrogen dioxide (NO_2) levels were measured before, during, and after stove usage for different fuel types, specifically natural gas, electric, and electric induction. Gas stovetops generated consistently higher NO_2 levels than induction and electric ranges; the average of stovetop trials surpassed recommended levels for sensitive groups defined by the EPA and WHO (0.099 ppm) by reaching 0.147 ppm. Emissions for gas stovetops and ovens were significantly higher than emissions from induction and electric burners, which remained near baseline. Notably, the average baseline NO_2 level, measured prior to range use, in apartments with gas stoves was higher than in those with electric stoves by a factor of 1.3 (p-value = 0.0002), demonstrating that gas stoves may impact indoor air quality even when not in use. The baseline NO_2 levels in apartments with gas ranges were three times higher than outdoor NO_2 levels measured by neighborhood sensors (New York City Community Air Survey, 2022). Finally, during lunch rush, we tested NO_2 levels in three commercial kitchens. The total average of each restaurant remained at healthy levels demonstrating the role for ventilation. Our work shows a significant difference in pollution associated with gas ranges compared to electric ranges, indicating a clear health risk, especially to vulnerable populations. This study supports legislation encouraging transitioning to electric and induction ranges in urban areas.

Turning Fat to Muscle by Activating Muscle-Specific Genes

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Obesity is a global health issue that impacts individuals of all ages, backgrounds, and socioeconomic statuses. Its consequences are severe, encompassing an elevated risk of chronic diseases like heart disease, diabetes, and certain types of cancer. Moreover, it leads to a diminished quality of life and a higher cost of healthcare. Thus, it is essential to identify the factors contributing to obesity and explore effective prevention and treatment strategies. Recently, we investigated the differentially expressed genes (DEGs) between inguinal white adipose tissue (iWAT) and thigh adipose tissue (tAT). From these DEGs, two muscle-specific genes, Myod1 and Myf6, exhibited especially high expression levels in tAT. This led us to hypothesize that the upregulation of Myod1 and Myf6 could induce 'browning' in white adipose tissue, thereby altering its metabolic function from energy storage to expenditure. To test this hypothesis, we utilized the CRISPRdCas9-VPR system, designing five guide RNAs (gRNAs) for both Myod1 and Myf6, packaging them into lentiviruses and introducing them into C3H10T1/2 cellderived adipocytes. Further qPCR analysis demonstrated the successful activation of Myod1 and Myf6 in the transduced adipocytes, which intriguingly coincided with an upregulation in two other myogenic genes of Myog, and Acta1, while simultaneously downregulating various adipogenic markers such as Adipoq, Cebpa, Cebpb, and Pparg1. Additionally, Oil Red-O staining revealed a decrease in lipid droplets within the white adipocytes, indicating the 'browning' of said adipocytes. This project establishes that the upregulation of Myod1 and Myf6 plays a pivotal role in the 'browning' of WAT, thereby offering promising prospects for the development of anti-obesity therapies.

The Use of Rhythmic Light Therapy to Entrain Gamma Oscillations and the Circadian System in Patients with Alzheimer's Disease and Related Dementias (ADRD)

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The increasing prevalence of dementia, particularly Alzheimer's disease (AD), has prompted an urgent exploration of interventions for patients, particularly those with Mild Cognitive Impairment (MCI), who are at heightened risk of progressing to AD. This study investigates the impact of a non-pharmacological intervention involving tailored light, specifically 40 Hz light, on neural oscillations, cognition, and sleepiness in individuals with MCI and age-matched controls.

Neural oscillations, notably gamma oscillations at 40 Hz, have shown promise in framing cognitive functions and their implications in AD pathology. Previous research in both animal models and humans has demonstrated the potential of 40 Hz oscillations in reducing AD pathology and influencing cognitive function. The posterior cingulate cortex and dorsal anterior cingulate cortex are emerging imaging markers we associated with AD, and alterations in cross-frequency bands have also been linked to such learning and memory impairments.

We pioneer a novel intervention, using light to enhance circadian entrainment and administer neurostimulation, to improve sleep and cognition in older adults with MCI and mild AD residing at home or in care facilities. We observed a range of benefits from this light intervention on alertness and cognition, with consistent enhancement in brain response across all participants.

Understanding the complexities of non-pharmacological interventions and their impact on cognitive functions is crucial for developing new therapeutic approaches. This study lays the groundwork for effective and non-invasive interventions targeting neural oscillations, offering promising avenues for the management of cognitive impairments, a venture that the US government alone spends $3.7 billion on.

A Multi-Agent Framework that Enables Graph Neural Network Communication in Real-World Robotics

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Drones use computer vision machine learning techniques to navigate their environments. Modern Graph Neural Network designs enable vastly improved perception for drones, but few systems exist to deploy this work outside of simulation. The goal of this project was to create a framework based on ROS that implements the communication necessary for Graph Neural Networks. The framework was composed of several customizable programs built on an industry-standard robotics framework. Preliminary testing was conducted by running the framework with an advanced depth estimation network on drones during flight tests. Across both autonomous and human-controlled flight, message passing between two drones was successful. Computational strain and network strain were measured at manageable levels. The framework was demonstrated to be effective in real robotics applications, with successful communication occurring during drone flight. Implementation with a modern Graph Neural Network could enable real-world perception that exceeds present-day capabilities. The framework bridges the gap between modern computer science research and real-life deployment.

De Novo Drug Design as GPT Language Modeling: Large Chemistry Models with Supervised and Reinforcement Learning

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In recent years, generative machine learning algorithms have been successful in designing innovative drug-like molecules. SMILES is a sequence-like language used in most effective drug design models. Due to data's sequential structure, models such as recurrent neural networks and transformers can design pharmacological compounds with optimized efficacy. Large language models have advanced recently, but their implications on drug design have not yet been explored. Although one study successfully pre-trained a large chemistry model (LCM), its application to specific tasks in drug discovery is unknown. In this study, the drug design task is modeled as a causal language modeling problem. Thus, the procedure of reward modeling, supervised fine-tuning, and proximal policy optimization was used to transfer the LCM to drug design, similar to Open AI's ChatGPT and InstructGPT procedures. By combining the SMILES sequence with chemical descriptors, the novel efficacy evaluation model exceeded its performance compared to previous studies. After proximal policy optimization, the drug design model generated molecules with 99.2% having efficacy $pIC_{50} > 7$ towards the amyloid precursor protein, with 100% of the generated molecules being valid and novel. This demonstrated the applicability of LCMs in drug discovery, with benefits including less data consumption while fine-tuning. The applicability of LCMs to drug discovery opens the door for larger studies involving reinforcement-learning with human feedback, where chemists provide feedback to LCMs and generate higher-quality molecules. LCMs' ability to design similar molecules from datasets paves the way for more accessible, non-patented alternatives to drug molecules.

New York-Upstate

Investigating Extracellular and Intracellular Antibody Immunity to Therapeutic Adeno-Associated Viral Vectors

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Gene therapies modulate disease-causing genetic mutations. Adeno-associated viral (AAV) vectors are adapted from wild-type AAVs to deliver these therapies. However, many people have been exposed to wild-type AAVs, creating immunological memory. This memory triggers extracellular antibody immune responses that prevent AAV-based gene therapies from being administered to patients. The cross-reactivity of AAV5, AAV8, and AAV9, viruses with varying genetic similarity, was tested using a murine model to determine if serotype cross-reactivity is low enough to allow for successful dosing despite pre-existing antibody immunity. Enzyme-linked immunosorbent titer assays (ELISAs) determined that AAV5 could be dosed to mice pre-immune to either AAV8 or AAV9, but AAV8 or AAV9 couldn't be dosed when pre-immunity existed for one serotype. Immunohistochemistry staining of liver samples confirmed these results. Although, in some cases, viruses may evade extracellular antibody immunity and still endocytose into cells, bringing attached antibodies intracellularly with them. Human immune systems have developed an intracellular Fc receptor called tripartite motif-containing 21 (TRIM21) against viral species similar to AAV. If TRIM21 launches an intracellular immune response to AAV as well, bypassing AAV immunity may be more complex than initially anticipated. A THP-1 based interferon and NF-kB reporter cell line was used to measure the TRIM21-triggered immune response to AAVs. A strong reporter signal was not detected for either pathway in this assay. This study supports that dosing a low cross-reactive serotype may be a viable method to evade AAV pre-existing immunity but did not elicit a TRIM21-triggered intracellular immune response to AAV.

Forecasting Post-Wildfire Vegetation Recovery in California using a Convolutional Long Short-Term Memory Tensor Regression Network

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The increasing wildfire frequency and size have posed growing challenges for re-establishing plants after wildfires, making the study of post-wildfire plant regrowth essential for creating effective plans to recover ecosystems. Previous research has predominantly focused on unraveling and analyzing the key ecological and biogeographical factors that influence post-fire succession. This research proposes a novel approach for predicting and analyzing post-fire plant recovery. Using the Normalized Difference Vegetation Index (NDVI) to quantify vegetation levels, a Convolutional Long Short-Term Memory Tensor Regression (ConvLSTMTR) network is created to predict future NDVI based on short-term plant growth data after fire containment. The model is trained and tested on 104 major wildfires in California from 2013 to 2020 with burn areas larger than 3000 acres. The integration of ConvLSTM with tensor regression enables the calculation of an overall logistic growth rate k using my model's predicted NDVI time series. Overall, my k-value predictions demonstrate impressive performance, with 50% of predictions exhibiting an absolute error of 0.12 or less, and 75% having an error of 0.24 or less. Finally, I employ Uniform Manifold Approximation and Projection (UMAP) and K-nearest neighbor (KNN) clustering to determine trends in similar post-wildfire recovery, providing valuable insight into areas of high and low recovery rate. My study pioneers the combined use of tensor regression and the ConvLSTM and introduces the application of UMAP for clustering similar wildfires. Taken together, this study contributes to the advancement of predictive ecological modeling and holds the potential to inform future post-fire vegetation management strategies.

Novel Annotations in Machine Translation Facilitate Language Acquisition: A Proof-of-Concept Study

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Language barriers cause limitations including isolation and scarcity of job opportunities. This study introduced a novel user interface (UI) prototype for a machine translator, intended to support a new method of passive language learning. The prototype provides syntactic and semantic annotations to decorate the input and output with the intention to quickly impart basic understanding of a foreign language. Participants in two treatment cohorts were asked to translate 20 pre-defined sentences from English into Japanese using the translator UI annotated via color-coding (n = 24) or tooltips (n = 15). A control cohort completed the same activity without access to either annotation, i.e., approximating a currently standard machine translation (MT) UI (n = 22). Next, participants completed an assessment of basic Japanese language proficiency. Results indicate that both styles of annotations significantly improved participants' language-learning process. Average assessment scores in both experimental groups were nearly double those of the control group ($p < .001$). To ensure robustness, a linear regression was run, taking possible confounding factors into account. Of these, only prior exposure to Japanese demonstrated significant exogenous correlation to assessment results; being in the experimental group retained significance ($p < .05$). The findings of this research suggest that this novel translator UI is efficacious. Including color-coding and tooltip annotations in MT can improve both the language-learning process as well as the accuracy of translated content. Making such annotations technically feasible beyond a prototype may be a worthy area of research for the fields of MT and natural language processing.

Language Models as Catalysts in EEG-Based BCI Speller Systems: A Low-Cost Solution for Paralyzed Patients

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Neuromuscular conditions, including amyotrophic lateral sclerosis, stroke, spinal cord injury, and cerebral palsy, are affecting nearly fourteen million people globally, hindering their ability to communicate. This study presents a novel non-invasive brain-computer interface (BCI) system, leveraging a commercially available EEG device (Muse 2) and a large language model (LLM) to enable communication for individuals with neuromuscular conditions. Utilizing EEG signals from eye movements, the system captures keywords which are then expanded into sentences using a pre-trained LLM (LLaMA-2). The EEG data, collected with the device's electrodes (TP9, AF7, AF8, TP10) under IRB approval, was used to train a 1-D convolutional neural network. This model classifies eye navigation in four directions from 0.25-second signals with 96.9% accuracy. Users input keywords through a simple interface, and the LLM, considering context like emotions and conversation history, generates varied sentences. This research evaluates the quality of the generated sentences by creating a single-sentence dataset (hospital500) and extracting keywords from the multi-turn dialogue dataset (DailyDialog). Compared to ground-truth sentences in these datasets, our system's top generated sentences (top 1) achieved sentence transformer-based text similarity scores of 0.86 and 0.74, respectively. The proposed system can achieve speeds of 200 characters per minute (CPM), a significant improvement over the 50 CPM of current non-invasive systems, but it still lags behind the 310 CPM of invasive systems. However, it reduces the cost to approximately 1/370th of an average BCI system, representing a substantial lowering of the cost-prohibitive barrier for people in need.

Examining the Benefits of Using a Swan Neck Rear Wing to Increase Stability and Fuel Efficiency in an Automotive Vehicle

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Aerodynamic drag and downforce are key factors in automotive design. To decrease drag and increase downforce, novel solutions are created and fluid flow around the vehicles' bodies is analyzed through different methods to test stability and efficiency. In this work, Ansys® Fluent, a Computational Fluid Dynamics (CFD) program, was used to analyze a swan neck type rear wing mount compared to a regular rear wing support to determine the optimal mounting for aerodynamic forces. The coefficients of forces and flow behavior were analyzed for ten 3-D researcher-prepared model configurations of the referential Ahmed Body with different mountings and the airfoil with different angles of attack mounted on top of the mentioned geometry. Through the calculations of forces and generation of contour and vector graphs, it was found that at both 0° and 15°, the swan neck rear wing mount was able to generate a similar level of downforce with the benefit of lowered drag. At 0°, the swan neck mount and the regular mount had drag coefficients of 0.32 and 0.37 respectively while having lift coefficients of -0.08 and -0.06 respectively. Similar benefits were achieved by the swan neck rear wing mount in the 15° case. My study revealed that many aerodynamic improvements, such as fuel efficiency, vehicular stability, and improved handling, are generated by switching from a regular rear wing mount to a swan neck mount on an Ahmed Body and supports using swan neck rear wing mounts to contribute to vehicular efficiency.

North Carolina

Finding The Percentage of Photon Passthrough in Materials Used in Solar Sails and Calculating The Acceleration at Different Sail Sizes

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Can different materials show greater photon propulsion, and what is the acceleration of the best performing material? If solar sailing was more efficient then it could be the new evolution of space travel, allowing us to cross an immense amount of space with little to no fuel. To make solar sailing more efficient, I'm testing different sail materials by finding the photon passthrough percentage. If a material is found that better suits solar sailing it could revolutionize space travel. To find the percentage of photon passrought, find the difference in wattage output produced by a solar panel and relate it to the amount of energy transferred through the sail. From there I used a NASA paper from 1967 that was translated from the Polish and a paper from 2007, both on solar sail theory, to find the acceleration of my solar sail. From there I can find the orbital dynamics and how to slow the sail down using a figure 8 pattern with Mars and one of its moons.

Silent Forests: Disentangling the Impacts of Climate Change and Deforestation on the Population of the Cerulean Warbler–A Public Data Analysis

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Migratory birds visit our hometowns annually greeting us with sweet songs and reminding us of the passing seasons; migratory birds, however, are especially vulnerable to climate change. Among these birds is the Cerulean Warbler. Over the past 50 years, their population has decreased from 2 million to 500,000–about 70%. Previous methods for identifying the reason for this decrease (banding and tracking) are time inefficient and expensive. This study, instead, uses free, public data sets to determine correlation between the decline of the Cerulean Warbler, deforestation, and climate change. Using statistical tests, this study identifies a strong correlation between deforestation and temperature rises with the decline of the Cerulean Warbler. It shows that a major reason for the decline of the Cerulean Warbler is deforestation; furthermore it proves deforestation in South America and North America are occurring at the same rate, meaning reforestation efforts to save the Cerulean Warbler and other migratory birds must be combined and with equal effort. A multiple regression formula using the correlated variables also serves as a way to predict Cerulean Warbler populations in the future as well as identify the amount of reforestation needed to restore the Cerulean Warbler population–120 billion hectares. Additionally, this project serves as a model for those seeking to identify reasons for population decline of any species. Public data sets are fairly unutilized in the conservation world, and this project gathers necessary data sets and serves as model to perform the same tests with other species.

Design, Facile Synthesis, and Evaluation of a Chalcone-Based Small Molecule ULK1 Agonist for the Treatment of Huntington's Disease

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Huntington's Disease (HD) is a fatal neurodegenerative disorder caused by a mutation in the huntingtin gene (HTT). This abnormal sequence codes for a mutated version of the huntingtin protein which accumulates as aggregates in neuronal cells, leading to neurological decline, disability, and death. Currently, no cure exists for HD and treatment consists of symptom management and supportive care. Studies have shown that using autophagy to clear mutated HTT protein aggregates may be a potential curative treatment option. The initiation of the autophagic process is mediated by the ULK1 complex. Previous research has demonstrated that pharmacologic agents can agonize this complex to clear protein aggregates, producing neuroprotective effects. This research aims to computationally design, synthesize, and evaluate a novel drug that improves upon these capabilities. Using computational modeling, a promising candidate with a chalcone pharmacore, B-21, was identified that shows improved docking at the activation site compared to a known ULK1 agonist and exhibits favorable pharmacological properties. This candidate was successfully synthesized, as determined by H-NMR, FTIR, and melting point analysis. This compound was then evaluated in a biological yeast model and it was determined that B-21 induces autophagy in that model. Together, these results demonstrate that B-21 is a potential therapeutic agent for promoting autophagy and clearing protein aggregates in the context of HD remediation.

Enhancing Ethereum's Security with LUMEN, Novel Zero-Knowledge Algorithms Generating Transparent and Efficient SNARKs Based on Hidden Order Groups

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Zero-knowledge rollups (ZKR), the best scalability solution for the cryptocurrency Ethereum, processes thousands of Ethereum transactions in a batch and uses zk-SNARKs (zero-knowledge succinct non-interactive arguments of knowledge) to verify the validity of those transactions. These zk-SNARKs rely on a trusted setup procedure, where a group of participants uses secret information about transactions to generate public information used by zk-SNARKs. However, this process introduces a security risk to Ethereum. Thus, researchers have been developing transparent zk-SNARKs that do not require a trusted setup. However, those transparent zk-SNARKs are often not as efficient as non-transparent zk-SNARKs. In this research, we developed LUMEN, a novel set of algorithms that includes a recursive polynomial commitment scheme and a new interactive polynomial oracle proof protocol, which is compiled into efficient and transparent zk-SNARKs with linear proof computation and verification time. Various techniques were creatively incorporated into LUMEN, including groups with hidden orders, Lagrange basis polynomials, a new amortization strategy, and auxiliary polynomials. Mathematical proofs were written to show LUMEN's completeness, soundness, and zero-knowledge, and we implemented LUMEN in Python and Rust. LUMEN's efficiency, measured in proof size, surpasses DARK and zk-STARK (two of the most efficient transparent zk-SNARKs) by 8 and 37 times, respectively, and LUMEN is only 2 times less efficient than Plonk, the most commonly used non-transparent zk-SNARKs. LUMEN is a promising solution to improve Ethereum's security while maintaining its efficiency and can significantly benefit the Ethereum market worth of 308 billion USD.

ANOMaLY: A Real-time Globalized System for Effective Regional Mitigation of Agricultural Nitrous Oxide Emissions

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Nitrous oxide (N_2O) is one of the largest contributors to the greenhouse effect (265x more greenhouse forcing than CO_2) and is the largest contributor to ozone depletion in the 21st century. Over 70% of anthropogenic N_2O is emitted directly from agriculture and soil management, and previous studies have observed that these emissions spike in localized spatiotemporal events. The system developed in this project identifies these events in real-time across the globe, allowing for fast and effective mitigation measures to be put in place to quickly reduce total emissions. Sentinel-2 imagery was correlated with soil chemical data gathered by the author from 7 farms across North Carolina over 6 months (1200+ samples taken) and used to extract novel spectral indices that approximate soil NH_4^+ and NO_3^- (R^2 = 0.53, 0.46). Existing data was paired with soil chemical data using the new spectral indices and was used to build an informed model that integrated partial differential equations modeling microbial nitrogen kinetics into a neural network architecture. This informed model explained ~80% of variation in regional N_2O a large improvement over previous models explaining only ~30% of variation. Due to this system using real-time satellite and climate data, localization of regional-scale flux hotspots can be achieved at nearly any place and time on Earth. At maximum capacity, this system can localize over 55% of total anthropogenic N_2O emissions and is generalizable to various agricultural gas-based pollutants. Additionally, the world's first spatiotemporally linked soil nitrate and ammonium dataset was developed for this project.

North Central

Using Spent Coffee Grounds to Make Biodegradable Films

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There is an immediate need to develop biodegradable alternatives to tackle the growing global problem of plastic waste. This research uses lignocellulosic material extracted from spent coffee grounds (SCG) to create environment-friendly packaging films. Films were prepared by dissolving the SCG extract (0.1, 0.2, 0.3, and 0.4 g) in ZnCl 2 solution (68%) and crosslinking with calcium ions (400 mM). They were characterized for moisture content, color, thickness, water solubility, water absorption, water vapor permeability, UV transmittance, tensile strength, elongation at break, and soil biodegradability. The SCG films are strong, and tensile strength increases with the amount of extract. They effectively block UV light and biodegrade within 15 days at 24% soil moisture. The outcome represents a significant step towards addressing the global plastic waste crisis and transitioning to more sustainable packaging solutions.

Mars or Bust: A Method to Build a Martian Regolith-Based Substrate for Sustainable Agriculture on Mars

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If humans are to settle on Mars, many barriers must be overcome including the need for Martian regolith-based agriculture augmented with minimal fostering materials from Earth. Unfortunately, Martian regolith is inhospitable to life. This study aims to develop an *in-situ* method using Martian regolith-based substrate to grow plants with dry biomass statistically non-inferior to that of control plants grown in Earth soil. Pre-experimental analysis indicated a variety of regolith augmentation is required to support plant life, including acidification, nitrogen fortification, microbe introduction, humus creation and drainage. Different treatments on simulated Martian regolith MGS-1 were tested, including introduction of varying levels of coco-coir, small amounts of Earth soil, and integration of biomass from previous growth cycles (green manure) into the substrate. Previous research produced reduced plant biomass with mixtures of >50% soil. This study has completed two growth cycles using just 4% Earth soil. After Growth 1 (G1), an ANOVA showed a significant F-stat ($p<0.01$) and t-tests showed all treatments inferior to control ($p<0.01$). After G2, significant growth in dry biomass over G1 was achieved; the 50% MGS-1 group +187%; the 60% MGS-1 group +79%. The G2 50% MGS-1 group achieved non-inferiority vs. the control ($p=0.36$). Therefore, the null is rejected. G3 plants at eight weeks are comparatively more developed than previous cycles and could show non-inferiority for groups with higher levels of MGS-1. This ongoing project is the first to successfully grow plants in MGS-1 substrate non-inferior to Earth-grown crops. Further research is needed.

SignalGrab: A Machine Learning Approach to Helping Color Blind Drivers

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There are nearly fourteen million individuals with color vision deficiency (color blindness) in the United States. Many individuals with color blindness struggle with differentiating between red and green traffic signals, particularly at night when other visual cues are unavailable. This can lead to traffic hazards imposing risk for both them and those around them. SignalGrab is a novel approach to solving this problem through a mobile Android app that drivers can easily use to help with recognizing traffic signals. SignalGrab uses a machine learning image recognition model built using TensorFlow and trained on a custom dataset of traffic signal images. The model is embedded in an Android app built using Android Studio. The app has a minimalistic design and provides audible information about the type of approaching traffic lights to avoid driver distractions. SignalGrab reliably solves the issue of traffic light recognition for color-blind drivers, and in real-life testing, it correctly recognizes traffic signals with an accuracy of 97.1 percent.

Blood Biomarkers for Recognizing Mild and Moderate TBI

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Today, there is no accurate way to diagnose Traumatic Brain Injury (TBI), especially when referring to mild or moderate injuries, and no way for medical professionals to guarantee presence and/or severity of some TBI. There is a gap of knowledge surrounding biomarkers of TBI, but they could be a promising solution to diagnosis issues associated with TBI. Some fluid biomarkers, such as those found in blood and saliva, are a noninvasive way for patients to get tests done and receive information on their injuries. This study aimed to identify potential fluid biomarkers that could be used to diagnose TBI. It involved three datasets sourced from the Gene Expression Omnibus (GEO), all three of which are blood samples. The analysis was done on mild and moderate level TBI that was inflicted in a variety of ways including via direct impact, sports injuries, and another undisclosed cause. Analysis was done using bioinformatics. With bioinformatics I was able to use online software to sift through and extract patterns from complex biological data. Specifically, samples were run through GEO2R, with secondary analysis using Venn diagrams and STRING cluster analysis. The cluster analysis provided me with biological processes of the most significant clusters. The analysis showed evidence that blood biomarkers could be a promising solution to the difficulties surrounding mild and moderate traumatic brain injury.

Bioremediation of Nickel with Chlorella Vulgaris and Chlorella Pyrenoidosa

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The purpose of this study was to compare the abilities of the microalgae strains Chlorella Pyrenoidosa and Chlorella Vulgaris to absorb various concentrations of nickel to evaluate their potential for bioremediation of contaminated water. It was hypothesized that there would be no significant difference between the two species' ability to absorb nickel, and no difference in removal efficiency would occur as concentrations changed within the range of the study. Three replicates were carried out under constant light and temperature conditions. Algae was grown in UTEX protose medium with nickel concentrations of 4 8 and 12µg/mL over 12 days. Final nickel concentrations were determined using a nickel assay, after which the interference of the growth medium was accounted for. The percentage of nickel removal was then divided by the optical density at 750nm wavelength (OD750) of the algae in each trail to account for differing algae masses. The hypothesis was rejected. Data showed a significant difference between the absorption effectiveness of C. pyrenoidosa and C. Vulgaris ($P=.002<.05$), with C. pyrenoidosa removing nickel more effectively in each concentration, which could be attributed to its larger size. However, no statistically significant difference existed between the absorption effectiveness of the algae at different concentrations ($P=.06$) or in how the two species reacted to increasing concentrations ($P=.1$).

Ohio

Designing and Testing UAV Propellers with Serrated Trailing and Leading Edges Inspired by Nocturnal Owl Flight to Reduce Noise and Improve Aerodynamic Performance

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Drones are infamous for their noise, and unfortunately, growing usage of UAVs across disciplines have increased noise pollution to negatively impact human health and the environment. Owls are known for their silent flight, with fringes at the trailing edges and leading edges of their feathers mitigating turbulent eddies and vortices, and thus, noise. This feature was implemented in a biomimetic propeller design for this project, observing the effects of each feature in question individually, as well as in conjunction to observe trailing-edge and leading-edge serration interaction. One control and five modified propellers with serrations were designed and 3D printed by the author, each possessing equal parameters. The trailing-edge fringes of the modified propellers were triangular with a height to wavelength ratio of 1:3. The leading-edge serrations had a 1:1 height-to-base ratio. The thrust and SPL at seven different speeds were recorded from 4000 RPM to 10000 RPM at 1000 RPM increments. Propellers that had both trailing-edge and leading-edge serrations were able to reduce noise at all RPMs, with a maximum of a 3.1 dBA reduction. Frequency analysis also revealed that noise levels by the control propellers were the greatest across the middle frequencies. Additionally, these modified propellers that possessed both features were able to increase thrust by 17.9%, a considerable improvement from last year’s designs that were tested. This project proved that propellers with biomimetic features can reduce noise pollution and energy consumption, in hopes of a more sustainable, noise-free future.

First Star Expansions: The Beginning of the Universe

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Halo expansions from the early years hide the mysteries of how the universe’s evolution allowed it to reach the point it currently is in. This is because its properties can be tracked from the beginning of its life to now, and its expansions quantified in order to be able to effectively illustrate how the universe had begun. This paper aims to find a mathematical model that tracks the ever-expanding nature of halos through a basic model in order to be able to create conclusions about how they have evolved. JUPYTER notebook is used with its matplot library and numpy library functions in order to plot, order and sort samples. Visuals and data organization is then done to find the expansion of the halo through mathematical calculation. Halo metallicity is tracked, and hence a metallicity cube is used with Renaissance Simulation data. The model used is one created by infinitesimally small ‘.’ markers that are used to fill up the halos. The halo areas and radii are then tracked to try and understand relationships present among these early halos. Results show that these

halos are much smaller than expected values, with a high left skew in terms of areas. They also show that the halo radii follow the normal model, which suggests the halo radii might be a random variable. This allows us to conclude the halos did indeed spread throughout each spatial coordinate, and this expansion can be explained through the use of a mathematical model.

Predicting Burn Injury Readmissions using Machine Learning Methods

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Hospital readmission rates are crucial indicators of hospital efficiency and the quality of patient care. While certain readmissions are unavoidable, many can be prevented, potentially easing the financial burden on families and government healthcare systems. Despite the unique risks and costs associated with burn injuries, few studies have investigated related readmissions.

Our research addresses this gap by evaluating the predictive accuracy of five widely used machine learning methods in forecasting readmission rates related to burn injuries through extensive simulation studies with various factors such as sample size, number of features, data dependency structures, and readmission rate prevalence. Our findings reveal that Support Vector Machine and Random Forest methods demonstrate the highest accuracy when the data signal is strong, and logistic regression models could perform competently in scenarios with weak data signals.

We apply these methods to the Nationwide Readmissions Database (NRD) and employ a random under-sampling strategy due to the significant data imbalance and a low readmission prevalence. Overall, the Random Forest method emerged as the most effective predicting method. We further identify five key factors influencing readmission likelihood: longer initial hospital stays and the absence of emergency department services at discharge increase readmission rates while being located in a major metropolitan area, initial weekend admissions, and primary insurance coverage through Medicaid or private providers are associated with reduced readmission rates.

These insights offer valuable guidance for physicians and policymakers in formulating strategies and guidelines to mitigate burn-related readmissions.

The Impact of Social Vulnerability Index Changes on Overall and Race-Specific Prostate Cancer One-Year Survival Over a 20 Year Period (2000-2020)

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The CDC's Social Vulnerability Index (SVI) measures an individual's health vulnerability based on their geographic location and environment. Previous studies have linked SVI at the time of diagnosis to cancer incidence and mortality rates. However, these studies have used only one SVI datapoint while using decades of cancer data, thus not incorporating how SVI changes over the time span of their cancer data. Here, the change in county-specific SVI values and their impact on the change in one-year prostate cancer (PrCa) survival rates were investigated, and it was hypothesized that no correlation would be found as previous research for correlation hadn't ever looked at changes over time. This was done for the overall population and by self-reported race from 2000-2020. SVI county-level data and Surveillance, Epidemiology, and End Results (SEER) data that met the eligibility requirements were kept and then were analyzed using chi-squared tests through R 4.3.1. Out of 1,006 SEER counties, 444 were eligible for the overall analysis, 397 for White PrCa cases, and 97 for Black PrCa cases. Most significantly, this novel study established positively correlated associations between SVI changes and one-year PrCa survival among the overall and White PrCa cases, which disproves the original hypothesis. Nevertheless, this study illustrated the necessity of looking at correlation through a change of time because it established a threshold for an

SVI and PrCa survival rate correlation, which previous research hadn't found. Further research is needed to generalize these findings to other cancers, stages of disease, and racial groups.

Development of Persistent DNA Vectors for Safe and Lasting Non-viral Gene Therapies

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Scaffold/MatrixAttachment Regions (S/MARs) are specific regions of DNA that help to stabilize chromatin structure and regulate gene expression by facilitating interactions between DNA and the nuclear matrix. Non-viral plasmid vectors used for gene therapy have severe limitations such as short-term cargo gene expression due to rapid loss of the plasmid DNA in the cell. The objective of this project was to develop a non-viral plasmid vector that is able to persist and replicate at high levels to combat the short gene expression from rapid loss and silencing of plasmid DNA. It was hypothesized that inserting S/MARs into proTLx-K plasmids would cause the GFP and luciferase reporter genes in the plasmid to persist and replicate at a higher level. The project used subcloning to insert an N-DISar2 S/MAR element into a proTLx-K plasmid that contained GFP and luciferase reporter genes. The resulting plasmid was transfected into M17 cells which had GFP, and luciferase intensity measured at intervals of every 5 cell passage. The cells transfected with the S/MARs proTLx-K plasmids were compared to a control group of cells transfected with proTLx-K plasmids that didn't contain any S/MARs elements. From passage 5 to passage 10, the GFP expression from the cell with a S/MAR containing plasmid increased by 104 RLU while the cell without a S/MAR decreased by 4322 RLU. S/MAR elements aided plasmids in tethering to and entering the nucleus, to transcribe and replicate the genes at higher levels.

Oregon

A Novel Entropy Based Heuristic Algorithm For Solving The Maximum Matching Problem In K-partite Hypergraphs

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The purpose of this research is to develop fast, efficient, and innovative algorithms to solve the maximum matching problem in *k*-partite hypergraphs using entropy-based heuristics. Matching in *k*-partite hypergraphs is a class of NP-complete partitioning problems in graph theory. 3D Matching (3DM), a special case of the problem when $k = 3$, was part of Karp's 21 original NP-complete problems. Graph matching, an active area of computer science research, has extensive applications in network flows, finding winning strategies in perfect information games, and problems involving scheduling and planning of resources. Worst case performance of a factor of k from optimum is an existing gap of traditional heuristic algorithms, 3DM-RND, as they do not use any information about the state of the graph. Entropy based algorithms iteratively build the solution by optimizing the state of the graph at each step. Two variants of the algorithm, 3DM-ENT1 and 3DM-ENT2, were developed and compared to 3DM-RND. The hypergraphs were transformed into a regular graph and an optimum solution was generated by iteratively moving to a least constrained state based on vertex degrees. On an average, 3DM-ENT1, 3DM-ENT2 and 3DM-RND were within 5%, 10% and 30% of the optimum solutions. 3DM-ENT1 and 3DM-ENT2 performed 30% better than 3DM-RND. The time complexity of 3DM-RND, 3DM-ENT1 and 3DM-ENT2 are $O(E^2)$, $O(E^3)$ and $O(E^2)$ respectively, where E is the number of hyperedges in the graph. A novel connection density metric was developed to characterize topological properties of graphs and predict expected performance.

Harnessing Heterotypic 3D Spheroid Culture Method for Pre-clinical Testing of Computationally Identified Biomarkers of Drug Resistance in Breast Cancer

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Over $10.8 billion is spent each year in oncology clinical trials. However, only 3.4% of those trials succeed. Precise selection of targets could greatly improve the outcome of these trials. I hypothesize that an integrated machine-learning approach with experimental validation using a 3D culture model will be able to predict the drug response and identify markers for drug resistance. I used a breast cancer clinical trial dataset with 998 patients. Feature selection was performed using the ExtraTreesClassifier. LightGBM predicted patient response for each drug with 94% accuracy after GridSearchCV tuning. SHAP and differential expression analysis prioritized the top 30 out of 16,000 genes. Network and CRISPR dependency analysis further pinpointed the top four functionally significant genes. Interestingly, numerous IGF1R pathway members are upregulated in drug-resistant samples, linked to poor survival in breast cancer patients, suggesting IGF1R is a promising therapeutic target. Next, I tested IGF1R inhibitor synergy with standard-of-care drugs in 147 double and triple combinations, providing better efficacy of triple combinations in 2D culture. Since cancer grows in 3-dimensional form, I established a novel 3-dimensional spheroid method by co-culturing cancer and endothelial cells. Flow cytometry and live cell imaging analyses demonstrated that IGF1R levels are high in drug resistance cells, and combining IGF1R inhibitor with chemotherapy increased cell death and reduced spheroid growth. I validated these results in three breast cancer cell lines. Overall, a machine-learning approach combined with parallel experimental validation identified new targets for clinical trials. My approach could apply to various cancers to improve patients' outcomes.

Electrogastrography and Personalized Transcutaneous Electrical Nerve Stimulation for Noninvasive, Lost-Cost Diagnosis and Treatment of Gastroparesis

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Gastroparesis, characterized by slowed or absent gastric contractions, affects 1.8% of the population, presents with severe nausea, abdominal pain, a high mortality rate, and incurs high treatment costs. The condition poses diagnostic challenges due to its symptomatic ambiguity, and current treatments are ineffective, invasive, and costly. This study introduces an approach that combines transcutaneous monitoring of gastric contractions using an electrogastrogram (EGG) with personalized transcutaneous electrical nerve stimulation (TENS) to diagnose and treat gastroparesis. A dual-model approach customizes TENS parameters based on individual body mass indices (BMIs) for optimal gastric contraction stimulation, specifically targeting the PC6 forearm acupoint to enhance gastric motility. Using computational modeling, a COMSOL Multiphysics finite element model simulates the distribution of current in tissue following stimulation, and a NEURON Simulation Environment model assesses nerve activation based on this extracellular current distribution. Optimal parameters are the minimal intensity settings that activate 100% of nerve axons. The EGG setup was validated through phantom testing, and the simulations by comparing their results against published data. The method was evaluated in an in vivo study. The participants all had BMIs in the 20 - 25th percentile, and received optimized pulse parameters: 18 milliAmperes amplitude, 400 microsecond duration, and 30 Hz frequency. After treatment, gastric contraction frequency immediately rose by an average of 35.39% ($p<0.01$). Remarkably, a 30.35% increase in baseline contraction frequency was maintained 48 hours post-treatment ($p<0.01$), as evidenced by EGG, highlighting the therapy's prolonged efficacy. At $1053.49 this method offers an affordable, effective alternative for gastroparesis management.

AR Surgical Navigation with Real-Time Carotid Artery Distance Monitoring and Tissue Visualization in Endoscopic Endonasal Surgeries using the Microsoft Hololens

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The intricate nature of endoscopic endonasal skull base surgeries, where surgeons reach the brain through the nasal cavity and sinuses, necessitates precise navigation to avoid inadvertent encounters with the delicate carotid arteries, which can precipitate severe neurological consequences. This is why an innovative system that combines imaging modalities with a distance calculation algorithm is being built to solve this critical problem. The program enables real-time visualization of the surgical field, allowing surgeons to have sight of the patient's critical tissues and organs through a camera embedded in their instruments, coupled with a continuous assessment of the range and separation between the surgeon's instruments and the carotid arteries. The interface is designed to issue immediate warnings when the calculated distance approaches or breaches a predetermined safety threshold, thus equipping surgeons with invaluable, instantaneous feedback. The surgeons wear the Microsoft Hololens, an augmented reality headset that allows them to see holograms displaying the distance and their surroundings. Furthermore, a custom convolutional neural network (CNN) was developed to extract intraluminal carotid artery models reliably from standard preoperative scans. By mimicking human visual processing, the algorithm achieves segmentation accuracy at around 91\%. Patient-specific models then become projected holographically onto the operative scene through the Microsoft Hololens. This comprehensive program enables tremendous change in the medical field, causing surgeries to be accomplished quicker and significantly improving the mortality rate.

Dual Machine Learning Architecture-Based Robotic Solution for Phytophthora Infestans Management and Mapping

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Phytophthora Infestans, generally referred to as potato blight, is a widespread, highly-infectious pathogenic disease among potato plants. Without immediate removal upon identification, its consequences on produce health are devastating. An average annual damage of $6.7 billion necessitates manual, systematic inspections for farmers, however, this process is labor-intensive and unsustainable. With current automated solutions being negligible, the implementation of an innovative, autonomous solution for potato blight management is crucial. Hence, a multi-faceted approach utilizing machine-learning algorithms, robotic automation, and mapping is developed. A robot utilizes a compact caterpillar drivetrain to navigate through rough, narrow terrain. To accurately identify blight, a webcam captures and parses image input through two machine-learning algorithms. The first is an object detection algorithm that locates individual potato leaves. Each respective leaf is subsequently passed into a Convolutional Neural Network that detects blight. Model optimization techniques including data augmentation resulted in a CNN accuracy of 99.88% and an RCNN mAP of 67.8%. To store blighted locations, a human-readable map of the crop rows is generated, highlighting blight-affected plants. Farmers are provided with updates of their crops' health via autonomous emails. A blighted crop row was simulated through strategically placed images containing healthy and blight-infected plants in realistic terrain conditions in order to evaluate performance. The robot was successfully able to identify every instance of blight through multiple trials. The promising results indicate that large-scale implementation and repurposing of this technology to combat a variety of plant diseases are feasible approaches in working towards universal crop-security.

Pennsylvania

Creating Digital Eyes for Visually Impaired Using Sensor Fusion and Stereo Vision

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This paper demonstrates "Digital Eyes" as a wearable navigation aide mounted under the visor of a cap that can both direct a visually impaired user towards a destination using GPS and scan the walkpath for tripping hazards along the way. Inspired by autonomous driving technologies, a stereo vision camera is used to generate the 3D terrain model of the road, and a computer vision algorithm abstracts obstacle info from >300,000 points per camera frame. Through sensor fusion with 3-axis accelerometer, the system can automatically compensate for the fluctuation in camera angle and height as a user moves and turns the head by transforming the domain model to the ground frame. Despite this complexity, the "Digital Eyes" achieved a 4 frames-per-second refresh rate with all calculations completed within 0.25s including the Random Sampling Consensus (RANSAC) based ground plane detection, cluster scan-based object isolation, Rotating Caliper based Oriented Bonding Box (OBB) generation, and tripping hazard in path voice alert scripting with quantitative locations and dimensions info. Text-to-speech based alert enables users to "see with ears" and announce current location using reverse geocoding from GPS coordinates to addresses. The innovation of this project in making high resolution and fast scanning possible with limited computation power was adopting Robotic Vision's techniques to focus on shape and sizes instead of following the beaten path of CNN based image recognition requiring significantly higher computation power and cost. This focus on the fundamental of tripping hazard detection makes this wearable assistive device affordable and practical.

A Study of Diversity and Abundance in Nasal Microbiome Transcriptomic Profiles Among Asthmatic Individuals

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Asthma, a predominant chronic condition among children, presents a multifaceted etiology, affecting 300 million individuals globally and imposing an $80 billion economic burden in the US alone. Recent strides in microbiome research have highlighted a pronounced link between microbiota dysbiosis and asthma pathogenesis, particularly within the gut microbiome, offering new avenues for intervention. However, the nasal microbiome, despite its critical exposure to external bacteria, remains inadequately explored. This study examines the Meta-transcriptomic profiles from nasal brushings of 694 asthmatic or healthy Puerto-Rican children, aiming to elucidate the role of the nasal microbiome in asthma.

Utilizing alpha and beta diversity measures, Wilcoxon test and Differential Abundance Analysis, we found that asthmatic patients were notably more diverse and abundant with certain pathogenic bacteria. Asthmatic individuals exhibited increased microbiota richness, evidenced by elevated values in Shannon's index (p = 7.6E-04). Noteworthy disparities in species abundances were also discerned; protective species like *Corynebacterium ammoniagenes* were downregulated in asthmatics (adj_p = 9.9E-3), while pathogenic strains like *Staphylococcus aureus* (log2FC = .12, adj_p = 7.95E-05) and *Staphylococcus pseudintermedius* (log2FC = .04, adj_p = 1.24E-07) were upregulated, aligning with existing literature.

Particularly noteworthy is the discovery of *Staphylococcus pettenkoferi* (log2FC = 8.50, adj_p = 4.50E-14), a relatively unexplored pathogen, which may hold significant implications for asthma pathogenesis. Our findings reinforce established research, introduce novel insights enhancing diagnostic precision and opening new research pathways. The study emphasizes the nasal microbiome's crucial role in comprehension and management of asthma, paving the way for future investigation in this underexamined domain.

Geometric Self-Supervised Learning: A Novel AI Framework Towards Quantitative and Explainable Diabetic Retinopathy Detection

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Diabetic retinopathy (DR) is the leading cause of blindness among working-age adults. Early detection is crucial to reducing DR-related vision loss risk but is filled with challenges. Manual detection is labor-intensive and often misses tiny DR-lesions, necessitating automated detection. However, existing automated systems are rarely used in clinical practice, solely classifying DR severity into different groups through an uninterpretable black-box process without providing valuable quantitative insight for precision medicine applications. In contrast, a quantitative detection system that identifies individual DR-lesions would overcome these limitations and enable diverse applications in screening, treatment, and research settings, but remains impossible to develop. The reason is that manually annotating diverse lesions is extremely time-consuming and challenging, limiting the amount of reliable data available to train an accurate model. To address this issue, this study presents geometric self-supervised learning, a novel framework for training a deep learning model without any manual annotations as ground truths to detect and segment the four most prevalent types of DR-lesions (i.e., microaneurysms, hemorrhage, hard exudate, and soft exudate) on retinal images, making it possible to utilize the millions of retinal images available for training. Geometric rule-based vision algorithms are utilized to identify and differentiate high-probability normal/abnormal regions and then extract image patches for training a U-net model. This novel framework was extensively verified on two public datasets, significantly outperforming all available studies in detecting and segmenting DR-lesions. It enables self-supervised training of any AI model to detect and segment DR-lesions, and its mechanism is generalizable to other segmentation tasks.

TTESSNet: Analysis of Transfer Learning for a TESS Exoplanet Classification Model

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NASA's Transiting Exoplanet Survey Satellite (TESS) presents an unprecedented volume of space-based photometric observations, with at least ~1,000,000 new light curves generated monthly from full-frame images alone. These data products must be analyzed efficiently and without bias to effectively process and classify light curves and handle the vast data throughput. With these requirements, automated planet candidate classification utilizing deep learning and convolutional neural networks has become an attractive alternative to human vetting. Currently, TESS's predecessor, the Kepler space telescope, has more research on exoplanet classification models and vastly higher performance. In this project, a transfer learning approach is applied to a TESS exoplanet classification model to bridge the divide and improve the performance and accuracy of TESS exoplanet classification. To conduct the experiment, a light curve preprocessing program was written to process light curves and transit data from the Q1–Q17 DR 25 TCE table, Kepler Science Data Processing Pipeline, and MIT's TESS Quick-Look Pipeline. A novel transfer learning approach in model training, where Kepler data is added during training, is analyzed. The results show that the approach noticeably improves the performance of TESS exoplanet classification when applied to both the testing data set and the ExoFOP catalog. Additionally, potential biases in classified populations are analyzed, along with the possibility of automated TESS vetting and population studies.

Ciliatine-Induced Apoptosis in Colorectal Cancer Cells: Targeting PPARδ for Tumor Suppression

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Colorectal cancer (CRC) is a leading cause of cancer-related deaths, and gut bacteria play a crucial role in its pathogenesis. Gut bacteria metabolize dietary substrates to produce various metabolites that can either promote or suppress CRC tumorigenesis. While many studies have focused on metabolites that promote

CRC, less attention has been spent on studying metabolites that exhibit anti-cancer activity. Discovering such compounds could lead to novel therapeutics. In this study, *Fusobacterium nucleatum* and *Escherichia coli* supernatants that are high in ciliatine, a representative phosphonate, were shown to inhibit the growth of COLO205 cells, a CRC cell line. Extended analyses involving diverse CRC cell lines (COLO205, HCT116, HCT15, and KM20L2) underscore ciliatine's anti-growth and anti-proliferative impact across the CRC spectrum, without affecting control human umbilical vein endothelial cells. Further mechanistic studies using flow cytometry revealed that ciliatine induced CRC cell growth inhibition through apoptosis (programmed cell death) rather than necrosis, concurrently arresting cells at the sub-G_0/G_1 phase. Structural modeling analysis suggested that ciliatine may impede CRC cell growth by binding to PPARδ. This discovery positions ciliatine as a hitherto unrecognized anti-cancer agent for CRC. The implications extend beyond a mere scientific revelation, promising novel therapeutic strategies for CRC management. Envisaging interventions that modulate gut bacteria populations, incorporate ciliatine into dietary supplements, or develop ciliatine-based drugs opens new avenues in the pursuit of effective CRC treatment. This study not only contributes to the scientific discourse but may lead to a paradigm shift in approaching CRC therapeutics.

Philadelphia and Delaware

Efficacy of the Use of Bacteriophages to Combat *Pectobacterium atrosepticum*

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In this experiment, bacteriophages vB_PatP_CB3, vB_PatP_CB4, and vB_PatP_CB5 were tested as potential methods of controlling the spread of *Pectobacterium atrosepticum*. First, the phages were selected based on the location of isolation. With the aid of computer processing, the phages were further narrowed down based on the specificity of the receptor-binding proteins for the protein receptors on the bacterium cell wall. In vitro testing was subsequently used to obtain further data regarding the efficacy of each phage, individually and in a cocktail. At the end of in vitro testing, it was concluded that the bacteriophage vB_PatP_CB5 produced a large quantity of plaques. This indicated successful cell lysis and bacteriophage propagation within the bacterial colony. Phages vB_PatP_CB3 and vB_PatP _CB4 produced no measurable plaques. It was therefore concluded that phage vB_PatP_CB5 is most effective at lysing and controlling growth of *P. atrosepticum*. With this conclusion, a phage-based commercial treatment can be produced to treat black-leg disease and limit the extent of crop damage.

Flexible Nanomaterial Sensors for Non-Invasive Health Monitoring

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Diabetes is the eighth leading cause of death in the United States, while about 1 in 5 patients are unaware that they have been affected. Being a diabetic, it is required to monitor blood glucose level regularly. Current needle-based glucose monitoring methods are invasive, painful, and easy to cause infection, so this strongly discourages people from early detection and management. Moreover, the invasive method requires to change supplies every week, it not covered by most insurance, which could be a constant burden for a family. Therefore, developing a non-invasive glucose monitoring technique is of utmost importance. But the complex components in blood may cause various adverse effects on the non-invasive measurement results. The research aims to address the limitations of existing invasive and non-invasive glucose monitoring by integrating nanomaterial sensors into wearables. GeSe, a flexible 2D material, is used for polarimetric sensors. After interacting with glucose molecules, the sensors measure light polarization for accurate, non-invasive glucose monitoring. The sensor is calibrated using known glucose concentrations and a machine-learning algorithm ensures reliability. Rigorous testing against traditional devices is done

through controlled studies on various objects to improve accuracy. GeSe-based nano sensor could revolutionize glucose monitoring because this approach not only establishes the viability of nanomaterials in transforming health monitoring but also highlights their potential to significantly improve the accuracy and convenience of blood glucose monitoring for individuals managing diabetes. The integration of nanomaterial-based sensors into wearable devices represents a noteworthy and disruptive stride towards enhancing the efficiency and accessibility of healthcare technologies.

Creation of Novel Living Plant-Based Hybrid Microbial Fuel Cell (H-MFC) Systems for Low-Power Electronic Applications

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This research focused on the development of a proposed novel plant-based hybrid MFC (H-MFC), with two different configurations (dry and wet). Additionally, three main factors of the MFC systems were studied: the effect of plants through rhizodeposition and photosynthetic efficiency, the impact of soil and its microbial characteristics, and the configuration design of an efficient MFC. All H-MFC systems were carefully constructed using three types of soils, six plants, and three electrode types. Power density from each system was calculated as a function of days. Statistical t-tests were applied for data analysis. T-test analyses showed that the differences between wet and dry systems were extremely statistically significant, with the wet system reducing internal resistance by more than 2 times and increasing power density by more than 3 times, showing the role of water content on power output capacity. Furthermore, the hybrid systems displayed significant advantages over their soil MFC (S-MFC) and plant MFC (P-MFC) counterparts, especially in sustained power output and lowered internal resistance, and reached a maximum power density of 0.28 W/m^2. The current proposed configuration designs have been implemented in three scaled-up real-world applications, first to power motion-activated lights in a house and backyard, second to power a wireless soil humidity and temperature sensor in a greenhouse, and third to power the humidity sensor in a golf course and show use especially in low-power field applications. This research suggests that plant-based hybrid MFC systems will be the future direction of S-MFC and P-MFC technology.

Chronic Sleep Deprivation Activates NLRP3 Inflammasome and Exacerbates Aβ Plaques Deposition in a Mouse Model of Alzheimer’s Disease

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Chronic sleep deprivation (CSD) is a condition resulting from insufficient sleep over a prolonged period of time, which affects one in three adults in the United States. Alzheimer’s disease (AD) is a progressive neurodegenerative disease and the most common form of dementia. Research has shown that people with CSD are more susceptible to developing neurological disorders such as AD in later life. However, the underlying mechanisms responsible for this link remain to be elucidated. The present study is aimed at discovering the underlying mechanism and identifying a potential therapeutic target to reduce the risk of CSD on AD. Here we show that CSD increased NLRP3 inflammasome activation in the brain of a mouse model of AD. Activated NLRP3 inflammasome co-localized with Aβ plaques, a pathological hallmark of AD, indicating that NLRP3 inflammasome may promote Aβ plaques deposition. Consistent with this hypothesis, increased Aβ plaque deposition was also observed after CSD in the brain of the AD model. Importantly, increased NLRP3 inflammasome activation was detected in the brain of wild-type mice post CSD, suggesting NLRP3 inflammasome can be activated independent of Aβ pathology and therefore upstream of Aβ plaques deposition in the brain of AD mice under CSD condition. Together, these findings support the hypothesis that CSD-induced inflammasome activation may exacerbate Aβ pathology. Future studies should investigate if NLRP3 inflammasome inhibitors can reduce Aβ plaque deposition post CSD, which may provide a new direction for the treatment of AD.

Puerto Rico

Discovery of New Extragalactic Planet Candidates: A Novel End-to-end Machine Learning Pipeline for Efficient Transit Detection in the X-ray Spectrum

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The discovery of M51-ULS-1b, the only known extragalactic planet candidate, introduced a vast new playground in modern astronomy—planetary formation under extreme environments. The finding simultaneously demonstrated that planetary detection techniques commonly employed in optical wavelengths, such as the transit method, can be adapted to the X-ray spectrum given X-ray emissions originating from accretion disks in X-ray binary systems (XRBS). However, despite enabling planetary detection, XRBS observations are sparse and noise-contaminated, thus presenting additional challenges in distinguishing genuine planet signals from system-generated variability. This study introduces the first end-to-end machine learning pipeline designed to automate the identification of eclipses and third-body candidates in XRBS observed by the Chandra X-ray Observatory. The pipeline covers data extraction, pre-processing, and feature engineering through advanced Bayesian block techniques into a random forest model (RFM). Using over 1500 real observations and synthetic examples, the model achieved an outstanding accuracy of 99.5% in identifying transits. Rigorous energy-independence testing was incorporated to ensure the consistency of transit effects across diverse X-ray energy bands. This not only verifies the nature of the transiting body but also enhances the reliability of transit predictions. The RFM's robustness is further substantiated through k-folding cross-validation and a validation set. In validation, the model successfully identified the transit of M51-ULS-1b and 13 new transits, spanning both extended-duration eclipses and brief-duration third-body candidates within eight distinct sources. This pipeline's success marks a significant advancement in automating the discovery of extragalactic planets, facilitating the discovery of promising targets for further investigation into planetary formation within complex systems.

Design And Construction of an Articulated Prosthetic Prototype Based on Fiberglass and Polylactic Acid for the Front Leg of a *Canis Lupus familiaris*

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The demand for prostheses for animals is still low, mainly due to the cost involved. A prosthesis is a device designed to replace a body part. These devices can be used on both people and animals. Worldwide, there are dogs that suffer from missing limbs, which affects their quality of life in the long term. The objective of this research was to create a prosthetic prototype based on fiberglass and polylactic acid capable of performing articulated movements for a *Canis lupus familiaris* (dog), being a way to contribute to the well-being of these species in a cost-effective manner. The prosthetic pieces were designed on the Tinkercad platform, and a fiberglass rod was used to create the prosthetic skeleton. The external structure was made from polylactic acid using 3D printing. With a series of formulas, the effectiveness of the prosthesis was proven. The results obtained demonstrate that the experiment was successful. The prototype proved to be resistant, and it was concluded that it is functional and suitable for use on a dog. In addition, the manufacture of the prosthesis proved to be an efficient way to reuse the polymer and a cost-effective tool in the creation of prostheses for animals, since it is 87% more economical than the prostheses found in the international market for animals.

Photodynamic Therapy Based on Eosin Y Transport Using Boron Nitride Nanotubes and Carbon Nanotubes to Induce Apoptosis in Pancreatic Cancer Cells

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Photodynamic therapy is the combination of a light source that stimulates a photo-sensitizing agent in an oxygen-rich environment triggering the production of singlet oxygen, causing apoptosis. Due to the complication in the detection and prevention of pancreatic cancer, it is proposed to determine if PDT based on the transport of eosin-Y through BNNTs and CNTs will be an effective method to induce apoptosis in pancreatic cancer cells. If the treatment in KPC cells treated with eosin Y, and both nanotubes produce $^1O_2$ and it maintains its high reactivity, then a higher concentration will induce oxidative damage and apoptosis in KPC cells. There were 4 Control Groups and 2 Experimental Groups. Group I was not altered, while nanotubes with eosin-Y were added to Groups II and III and cell irradiation was avoided. The IV was irradiated without the presence of nanotubes or eosin-Y. The Experimental Groups were treated with nanotubes and eosin-Y together with cell irradiation. The effectiveness of the treatment was determined by performing a T test. The eosin-Y samples together with BNNTs and CNTs at 25% turned out to be statistically different at a significance level of 80%. At a concentration of 100%, the BNNT solution was found to be significantly different at a level of 80% and the CNTs solution at a level of 90%. As the concentration of the solutions increased, to 25 and 100%, the values became statistically different. PDT performed on pancreatic cancer cells with both solutions was found to be effective.

Comparing the Success Rate for *Acropora palmata* (Elkhorn Coral) Outplanting between Local Volunteers and NOAA Marine Biologists in Puerto Rico

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Elkhorn coral, *Acropora palmata* is a threatened species in the Caribbean. The degradation of the *A. palmata* population stimulated rehabilitation initiatives. This study analyzed the survivorship of *A. palmata* outplanted on an inner reef of a fringing reef system located in Shacks Beach, Isabela, Puerto Rico. It compared the success rates of community volunteers to NOAA marine biologists. Results analyzed the success rate of *A. palmata* fragments to support future outplanting initiates in Puerto Rico. This led to the research question: “Does the success rate of outplanting *A. palmata* in the inner reef system located in Shacks Beach, Isabela, Puerto Rico correlate with the level of experience of the outplanter?”

The *A. palmata* coral fragments were transferred from a fixed bottom coral nursery structure. They were secured on a rocky substrate by NOAA Marine Biologists and community volunteers using Portland Cement. I predict no statistically significant difference comparing the survivorship of outplanting coral fragments. Therefore, community outreach is an effective method to implement rehabilitation efforts.

In conclusion, the *A. palmata* coral fragment outplanting short term survival rate of the community volunteers is within 12% difference than the NOAA Coral Propagation Project’s survival rate. Through awareness and effective hands-on training, this group may provide a significant role in the revival of degraded coral reefs. This will encourage the training of volunteers to collaborate with trained marine biologists in the development of coral nurseries and outplanting projects in their community.

Modeling of Amino Acids' Chemical Reactivity Against Cancer

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Chemistry of amino acids is incredibly versatile, they are fundamental building blocks, playing a vital function in a variety of bio-chemical processes. They are composed of an amino group (-NH2), a carboxylic acid group (-COOH), and a distinct side chain attached to a central carbon atom. The composition and structure of this variable side chain determines each amino acid's distinct properties and functions in variety applications. Using the APD database as the primary data source, theoretical modeling research was conducted on various amino groups and their properties in relation to amine composition, size, 3-dimensional structure, positive charge at the amino group, and the type of organic chain's length. There were 1,547 physico-chemical features extracted with the propy package in Python, and these features characterize the sequence through the percentage of each amino acid present in the sequence (amino acid composition, 20 features); the percentage of each pair of amino acids in the sequence (total of 400 features); the correlation between pairs of amino acids in a specific feature, such as charge, at various distances, and various other features that describe the peptide in terms of polarizability, free energy, van der Waals forces. We discovered that the positive charge of amino acids influences their reactivity with negatively charged lipids. Another important factor in reactivity against cancer was hydrophobicity, which is determined by the amino acid's structure. These findings could benefit experimental chemists by pre-selecting specific groups of amino acids based on their targeted reactivity against cancer, saving time in experiments.

South Carolina

The Effect of Different Concentrations of *Bacillus subtilis* on *Spirulina platensis* Growth in an Environment with Glyphosate

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Red tides are a significant issue along the coasts of several countries around the world. These red tides consist of algae that grow at an expedited rate, resulting in many issues for the surrounding environment. The purpose of this study was to see if adding *Bacillus subtilis* at different concentrations would decrease *Spirulina platensis* growth in an environment with glyphosate. It was hypothesized that in an environment with glyphosate, a 30% *B. subtilis* solution would decrease *S. platensis* growth at a greater rate than a 0% or 15% solution because *B. subtilis* has the ability to degrade glyphosate and reduce the amount of nutrients available for *S. platensis.* To conduct this study, different concentrations of *B. subtilis* were made by diluting a bacterial solution in distilled water, respectively. Then, 5 mL of the *B. subtilis* solution, *S. platensis,* and glyphosate were added into a petri dish and placed in a dark drawer for 96 hours. Afterward, a SpectroVis spectrophotometer was used to measure the absorbance of the *S. platensis* in each petri dish as an indicator for colony density. The results showed that adding *B. subtilis* at different concentrations decreased *S. platensis* growth by 80.4% in the 15% solution and 88.9% in the 30% solution. A subsequent one-way ANOVA test showed the data was statistically significant since $F(2, 87) = 374.46$, $p<0.001$, which means there is enough evidence to reject the null hypothesis. The results indicate that *B. subtilis* was successfully able to decrease *S. platenis* growth by degrading the glyphosate.

Reducing Tracheal Complications in Endotracheal Intubation Patients Using Automated Cuff Pressure Modulation

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Endotracheal tube intubation is the third most frequent procedure, performed approximately 13-20 million times yearly in the United States (Mosier et al., 2020). Despite the regularity of the procedure, intubation-related complications such as tracheal injuries, laryngeal injuries, and ventilator-associated pneumonia are ubiquitous due to improper cuff pressure management methods (Ganti et al., 2018). Current techniques, such as the pilot-balloon and minimal-leak technique, have proven ineffective and inconsistent in managing pressure. As a result, over 71.6% of intubation patients have abnormally high cuff pressures (Ramírez, 2014). Therefore, the purpose of this research was to design an endotracheal tube with automated cuff pressure modulation synced with the respiratory cycle; increasing and decreasing cuff pressures as patients inhale and exhale theoretically relieves pressures placed on the trachea during intubation and can reduce many of the complications associated with endotracheal tubes. The device was designed using two pressure sensors to evaluate the instantaneous pressure and cuff pressure, two DC motors to inflate and deflate the cuff, and an Arduino microcontroller to control the units. To test the device for its functionality, air was blown into the tube to simulate intubation and the respiratory cycle, and the responding cuff pressure was monitored. The results found that the endotracheal tube successfully automatically modulated the cuff pressure to pressures of 25 cmH_2O and 14-15 cmH_2O with the respiratory cycle. Therefore, the proof-of-concept design to modulate the cuff pressure of endotracheal tubes presented a viable solution to reduce intubation-related injuries for millions of patients across the world.

The Association Between Demodex Folliculorum and Demodex Brevis and Common Skin Diseases

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This research project will discuss the extent to which Demodex Folliculorum and Demodex Brevis, microscopic face mites, have a significant role in acne vulgaris in teenagers. Acne vulgaris is a common skin condition affecting around 85% of teenagers in the United States, causing 20% of teens to develop permanent facial scarring. This study addresses the potential correlation between these face mites and teenage acne vulgaris, hypothesizing that they are more prevalent in teenagers with moderate to severe acne, compared to those with level 0 or clear skin. Using a mixed-methods approach, the study incorporates a case study and interviews with teenagers. The severity of acne will be evaluated using the Investigators Global Assessment (IGA) scale (a scale from 0-4), where 0 is clear and 4 is very severe. At the same time, the collected data will be analyzed to analyze the potential correlation between Demodex mites and acne severity. The case study involves the collection of skin material from teenage participants, followed by microscopic examination to determine the presence of Demodex mites. Similarly, interviews with teenagers will provide many insights into the prevalence and significance of Demodex mites in the context of teenage skin conditions. This could indicate hormone influences, medication influences, and more. Ultimately, this study seeks to examine the relationship between Demodex mites and teenage acne, contributing valuable insights into the pathogenesis of this widespread skin condition, with the ultimate goal of enhancing our understanding and potential treatment strategies for teenagers struggling with acne.

The Effect of Chlorhexidine on the Fluorescence of Dugesia tigrina in a Planarian Toxicity Fluorescent Assay

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Eye irritation tests are conducted to determine the toxicity of chemicals in eye products that may be potentially harmful to humans, animals, and the environment. However, many ocular irritation tests are seen

as inaccurate, unethical, and expensive. These issues suggest that there needs to be more research conducted on ocular irritation tests. The purpose of this study was to determine how chlorhexidine, an eye drop preservative, affects the fluorescence of *Dugesia tigrina* in a planarian toxicity fluorescent assay. This research will help determine if the planarian toxicity fluorescent assay is valid for evaluating eye irritants. It was hypothesized that higher concentrations of chlorhexidine would result in higher fluorescence in *Dugesia tigrina* than lower concentrations of chlorhexidine. The *D. tigrina* were put in 0%, 0.004% and 0.02% concentrations of chlorhexidine for one minute. Then, they were placed in sodium fluorescein for one minute and placed under UV light. Pictures were taken and the fluorescence was evaluated in ImageJ. A one-way ANOVA ($F(5.36E\text{-}6, 0.0001) = 90.1261$, $p < 0.0001$) was conducted and one or more significant differences were found between the groups. A post-hoc Tukey Kramer test was used to determine where the differences were. Each concentration group was found to be significantly different from the others. The results supported the hypothesis that higher concentrations of chlorhexidine would result in higher fluorescence. These results indicate that the planarian toxicity fluorescent assay can be used to detect different concentrations of eye drop preservatives.

The Effect of *Vernonia anthelmintica* Extract on α-synuclein Overexpression and Lipid Content in *C. elegans* Strain NL5901 for Parkinson's Disease and Diabetes Application

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Despite Parkinson's disease and diabetes being leading causes of death worldwide, there are still issues finding affordable treatments (Associated Press, 2022). The purpose of this experiment was to test *Vernonia anthelmintica*, a common folk medicine herb, as a protective agent against α-synuclein and lipid buildup in *C. elegans* strain NL5901 which are genetically modified to contain YFP for α-synuclein, a protein that can lead to Parkinson's if misfolding occurs. A decrease in α-synuclein should increase lipid levels, reducing insulin inefficiency and slowing the progression of diabetes (Stoker & Barker, 2020). It was hypothesized that *V. anthelmintica* would decrease α-synuclein and increase lipid levels. *E. coli* OP50 was obtained and mixed with *V. anthelmintica* extract at various concentrations depending on the experimental group (0 and 5 µL), which served as a feeding solution for the *C. elegans*. After incubation for 48 hours, the *C. elegans* were washed with M9 buffer for the α-synuclein trials and analyzed using a fluorescent microscope. Lipid trials were placed in a solution of Nile red, a lipophilic stain, and washed using PBST instead. An independent t-test found that a 5 µL concentration affected the fluorescence intensity of α-synuclein ($t(58) = -2.339$, $p = 0.024$) and lipid content ($t(15) = -16.131$, $p < .001$), discovering significant differences between the control and 5 µL concentrations for both variables. The results of this experiment suggest that *V. anthelmintica* can be utilized as a treatment for type-2 diabetes and a potential cure for Parkinson's disease.

Southwest

Development of Propellers

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In 2017 MIT introduced a patent for a revolutionary type of propeller. Later, in the beginning of 2023, champions for the new technology arose praising the benefits of reduced drag and increased efficiency. These substantial benefits are shown in all kinds of fluid. This project focuses on whether or not this new design increases thrust as well. To produce these results, we used two types of 3D printed propeller designs along with a simple fixed pitch propeller. By placing the propellers onto the motor of an assembled RC aircraft we used a manometer to measure the amount of thrust produced. Each test was repeated three times per propeller design. These findings indicate a net decrease in thrust when using either of the new 3D printed propellers. The disparity in my data could be caused by several factors. Those factors include an increase in overall weight when using the new design, or the increase in diameter of the two printed propellers. A possible solution to this issue could be the use of a different type of printing material and/or an infill design or a reprinting of all the propellers to minimize the amount of variables across the experiment. In conclusion, this experiment proves that the different aspects of propeller design changes the characteristics of thrust, drag, and noise produced by the propeller.

A Realtime Camera Fusion 3D Model with a Novel Feature-Matching and Star Identification-Based Calibration for Tracking Wildfires

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Smoke plumes produced by wildfires pose a major threat to public safety. However, a lack of accurate real-time information on smoke plumes provided by current methods such as satellite imagery leaves communities unable to make informed decisions critical to ensuring the safety of themselves and their families. Despite the current lack of smoke plume information from satellites, there is an abundance of photography of smoke plumes. In order to utilize this untapped source of information, this project aims to provide an accurate and quick method to locate smoke plumes through smartphone cameras.

This paper proposes a method to calibrate a camera using manual and automatic pixel correspondences, an important step for rendering large, homogeneous objects at a distance accurately. After calibration, the proposed method renders a real-time 3D smoke plume with planar-to-planar correspondences. This algorithm proves to be significantly faster and more granular than current satellite imagery methods (MODIS and HMS), a significant achievement given the reliance of research methodology and public safety decision-making on previous methods.

Effectiveness of Insect Management Practices on the Spread of Potato Virus Y

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This study investigates Potato Virus Y (PVY) in potato crops, a virus that significantly impacts yields for farmers nationwide. PVY is an infectious virus transmitted from plant to plant through aphids, which can feed on diseased plants and spread the virus to healthy ones. This study compares two pest management practices for controlling the spread of PVY in food crops by managing the vector (aphid). The two methods are crop-oiling and companion cropping (regenerative). Samsun tobacco plants were used to monitor the spread of PVY due to its low resistance to PVY infection and good expression of PVY symptoms. Plants were grown from seed, nurtured in a greenhouse, and then transplanted in two separate sets on June 8th and July 13th, 2023. Leaves from each plant were sampled on August 24th and tested for PVY presence. Companion cropping yielded completely negative PVY results in all field locations, whereas crop-oiling fields demonstrated a positivity rate from 50% to 70%, particularly at the perimeter of the field. Based on these findings, companion cropping emerges as a more effective method in preventing the spread of PVY to important food crops. Adopting this holistic approach provides proactive measures by; 1) establishing favorable habitats and food sources for beneficial insects, and 2) providing aphids with multiple opportunities to purge PVY from their mouthparts before feeding on the primary food crop. This study shows the potential of companion cropping as a sustainable and effective method for mitigating the spread of PVY in potatoes.

Help! I Need Somebody: An Assistive Device That Notifies Emergency Services Once a Fall Has Been Detected

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36 million falls are recorded every year among the elderly population. 32,000 of those falls result in death. There are fall detection devices already available, but they are expensive and only detect falls 85% of the time. Those fall detection devices use an accelerometer and gyroscope to measure if a fall has occurred, rather than using vitals. They also do not directly call emergency services or emergency contact. Instead, they notify a 24/7 monitoring center and they make the call. I developed a device that utilizes two modules, an accelerometer and pulse oximeter. With these modules I set constraints that when exceeded a timer would countdown from 20 seconds. The user would have 20 seconds to press a button that would tell the timer to shut off and reset the device. If the button is not pressed within 20 seconds, a pre-recorded message is sent to the attached bluetooth device through a bluetooth module. The pre-recorded message would include information that might affect patient care, like the user's location, list of pre-existing conditions and medicines, and any allergies that could put the user at risk. By using data from a pulse oximeter and accelerometer modules, the device was able to accurately detect if a fall had occurred. The device looked for an extreme increase in heart rate and zero movement to detect a fall. This device could be utilized by older adults that are at risk of falling and still want to live independently.

A Two-Pronged Method for the Identification of Highly Biocompatible Nanomaterials

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Nanoparticle (NP) toxicity analysis is critical for minimizing their potential harm to the biological system through non-specific uptake. To this end, this study introduces a machine learning pipeline focused on model explainability for predicting NP toxicity, utilizing an *in-vitro* dataset (*N* =10,856 samples) characterized by 20 physicochemical properties and experimental conditions. It leverages feature selection algorithms and SHapley Additive exPlanations (SHAP) to pinpoint critical toxicity determinants, employing the Gradient Boosting Classifier, which outperformed 24 models with accuracy and recall of over 90%, to identify seven key parameters influencing toxicity. The model's robustness was confirmed through external verification (*N* = 135 samples) and application to an in vivo dataset (*N* =126 samples), both showing over 85% accuracy, indicating transferability. The second half of the study explores the effect of lipid subcomponents on Lipid Nanoparticle (LNP) cytotoxicity in Prostate Cancer and Human Embryonic Kidney (HEK) cells, marking the first comprehensive assessment of lipid subcomponent impact on toxicity. It reveals the necessary helper lipid quantity to mitigate the toxic effects of highly positive NPs in HEK Cells, prompting a reevaluation of charge impact on NP toxicity. PEG and Cholesterol were deemed non-toxic, with all LNPs found non-toxic to Prostate Cancer Cells. This dual approach aims to enhance nanoparticle identification and elimination in drug development, offering potential cost and time efficiencies.

Tennessee

FusionPro: A Recurrent-Neural-Network-based Program to Accelerate Construction of Fusion Proteins towards Drug Discovery

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Fusion proteins play a critical role in drug discovery by modeling protein complexes, facilitating protein purification, and allowing researchers to monitor expression. Prerequisite to visualize their structure is the creation of clonable DNA constructs that encode the desired proteins. There are numerous processes to create these recombinant plasmids. IVA (In Vivo Assembly) cloning has emerged as the most efficient method; however, planning for fusion protein assembly using IVA is error-prone and time-consuming. To address these issues, FusionPro utilizes recurrent neural networks and validation programs to generate optimal primer sets and a corresponding, clonable DNA construct. The program eliminates the production of a sequence that encodes the wrong protein by generating all possible open reading frames from the inputted plasmid sequences and leveraging them to verify the final construct. It optimizes the linker and primers through a bidirectional long short-term memory-based architecture that uses the plasmid sequences as context. FusionPro also significantly reduces planning time from hours to under fifteen minutes by cutting the myriad of components researchers must consider to seven user inputs. The program was tested to create four versions of a GluA1-γ5 tethered construct; western blot analysis confirmed the successful creation of all versions of the fusion protein. DNA sequencing further showed that the recombinant plasmids created using the generated primers matched the constructs predicted by FusionPro. This research illustrates that leveraging artificial intelligence in fusion protein assembly may yield optimal results while significantly reducing planning time, therefore accelerating protein structure research and drug discovery.

The Parthenogenetic Predicament: The Effects of Varying Environmental Sizes on *Lepidodactylus lugubris*

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This experiment was conducted to see if a shift in enclosure size can have a substantial effect on mourning gecko reproductive rates. Six mourning geckoes were split evenly into two groups. The groups were placed into two enclosures, one being 12x12x24 and the other being 18x24x36. The enclosures were regularly monitored for three months, and any clutches of eggs laid were documented, with a thorough check to ensure all clutches were found being done at the experiment's conclusion.

The experiment found that the second group (in the smaller enclosure) laid ten total clutches of eggs, with eight being the standard double clutches of eggs and two being single egg clutches for a total of eighteen eggs. The first group (in the larger enclosure) laid six total clutches, with four being double clutches and two being single clutches for a total of 10 eggs. These findings support the hypothesis that mourning geckos reproduce more rapidly in a smaller enclosure.

Adversarial AI: Poking Holes in Classification Algorithms

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Machine learning models are prone to adversarial attacks, where inputs are manipulated to cause misclassification. While previous research has focused on techniques like Generative Adversarial Networks

(GANs), there's limited exploration of GANs and Synthetic Minority Oversampling Technique (SMOTE) in text classification models. Our study addresses this gap by training various machine learning models and using GANs and SMOTE to generate additional data points aimed at attacking these models. Furthermore, we extend our investigation to face recognition models, training a CNN and subjecting it to adversarial attacks with perturbations.

Our experiments reveal a significant vulnerability in classification models. Specifically, we observe a 13% decrease in accuracy for the top-performing text classification models post-attack, along with a 66% decrease in facial recognition accuracy. This highlights the susceptibility of these models to manipulation of input data. Adversarial attacks not only compromise the security but also undermine the reliability of machine learning systems. By showcasing the impact of adversarial attacks on both text classification and face recognition models, our study underscores the urgent need for robust defenses against such vulnerabilities. Addressing these vulnerabilities is crucial for ensuring the trustworthiness and effectiveness of machine learning applications across various domains.

Structure Predictor: A Machine Learning Algorithm to Reliably Fit Thin Film Neutron Reflectivity Curves

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Mentor: Mathieu Doucet, Oak Ridge National Lab

Neutron reflectometry is a technique for studying the structure of thin films. Thin films are layers of materials that simulate systems with only the processes a scientist is interested in. Interactions between materials, such as new layer growth on a battery or the strength of a protective coating, can be studied at the nanometer scale with a technique called neutron reflectometry. Data gathered from neutron reflectometry can be used to plot a neutron reflectivity (NR) curve from which the number of layers and the corresponding thickness, roughness, and scattering length density of each layer can be extracted and evaluated to understand how the materials interact. Currently, NR curves are manually fit with multiple parameters, which is time consuming. Machine learning algorithms offer classification capabilities that may be more time efficient. A Python package, Structure Predictor, was created using k-Nearest Neighbors and convolutional neural network algorithms which provides three methods for predicting the number of layers and parameter values of a NR curve. The accuracies of the three methods range from 66.6% to 73.5% indicating Structure Predictor to be a reliable supplement, or even alternative, to manual NR curve fitting.

Iterative Misclassification Error Training (IMET): An Optimized Neural Network Training Technique for Medical Image Classification

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Deep learning models are being tested to analyze medical images for a variety of applications, ranging from identifying diseases to accurate predictions. However, the amount of data available for some medical conditions is extremely limited, which hinders model performance. In this research, Iterative Misclassification Error Training (IMET), a novel training technique, is proposed to optimize and improve the performance of deep learning models. IMET works by iteratively updating the training data for each train through both misclassification error and equal class sampling. The misclassification error per class is calculated after each train and comprises 50 percent of the data used for the next train. An equal sample from every class makes up the other 50 percent of the data, which ensures overfitting does not occur. The IMET technique achieved accuracies of 80.3% and 90.2% on the OCTMNIST and PneumoniaMNIST datasets, respectively, in comparison to 77.6% and 88.6% obtained by the benchmark models. The IMET technique outperformed the benchmark models with both a significantly lower parameter count (roughly 366 times smaller than the ResNet-18 and 765 times smaller than ResNet-50) as well as a lower number of training samples (87,000 in comparison to the 97,000 for OCTMNIST and 2800 compared to the 4700 for PneumoniaMNIST used by the ResNets). The proposed IMET technique therefore shows that, through the development of novel neural network training techniques, increased accuracy and enhanced performance on medical imagery can be achieved.

Texas

Aqua-Arsenic Remediation

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According to the US Department of Agriculture, drought decreases the crop yield of rice, the most common source of nutrition worldwide, by nearly 18%. Coupled with arsenic contamination in the soil, total rice yield is reduced by 45%, and the World Health Organization reports that arsenic contamination threatens the livelihoods of over 150 million people worldwide. Existing solutions focus on either heavy metal or drought remediation, but not both. Examination of the *Oryza sativa* metagenome via the National Center for Biotechnology Information (NCBI) database revealed promising candidates within the aquaporin gene family capable of efficiently mitigating both arsenic toxicity and drought stress. Rice cotyledons were genetically augmented with arsenic-resistant *OsNIP2;1* and *OsNIP3;2* genes, and drought-resistant *OsPIP2;2* genes both individually and in combination. In moderate drought conditions and 25 ppm arsenic-contaminated soil, transgenic plants were observed to have length and color similar to the positive control plants, corroborated by chlorophyll content. In contrast, the non-transgenic plants were much shorter in length and appeared wilted. After eight weeks, the roots of the transgenic plants contained more than 20 ppm arsenic, but arsenic was undetectable in the leaves due to decreased arsenic translocation from root to shoot. In addition, the soil arsenic content showed an 80% decline from a 25 ppm baseline to 5 ppm with transgenic rice plants. Statistical significance was proven using two-sample T Tests. Thus, aquaporin-augmented *Oryza sativa* offers a promising solution to mitigate both arsenic and drought stress in rice plants, improving crop yield and facilitating soil decontamination.

Simulation-aided Learning from Demonstration for Robotic LEGO Construction

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Recent advancements in manufacturing have a growing demand for fast, automatic prototyping (i.e. assembly and disassembly) capabilities to meet users' needs. This paper studies automatic rapid LEGO prototyping, which is devoted to constructing target LEGO objects that satisfy individual customization needs and allow users to freely construct their novel designs. A construction plan is needed in order to automatically construct the user-specified LEGO design. However, a freely designed LEGO object might not have an existing construction plan, and generating such a LEGO construction plan requires a non-trivial effort since it requires accounting for numerous constraints (e.g. object shape, colors, stability, etc.). In addition, programming the prototyping skill for the robot requires the users to have expert programming skills, which makes the task beyond the reach of the general public. To address the challenges, this paper presents a simulation-aided learning from demonstration (SaLfD) framework for easily deploying LEGO prototyping capability to robots. In particular, the user demonstrates constructing the customized novel LEGO object. The robot extracts the task information by observing the human operation and generates the construction plan. A simulation is developed to verify the correctness of the learned construction plan and the resulting LEGO prototype. The proposed system is deployed to a FANUC LR-mate 200id/7L robot. Experiments demonstrate that the proposed SaLfD framework can effectively correct and learn the prototyping (i.e. assembly and disassembly) tasks from human demonstrations. And the learned prototyping tasks are realized by the FANUC robot.

A Novel Quantum-based Model of the Cortical Canonical Microcircuit

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Most complex systems are made up of simple, repeating functional units. There has been great controversy over whether such a unit, a ‘canonical microcircuit’, makes up the cortex of the human brain. Although abundant evidence demonstrates uniformity in structure and function across the cortex, determining the exact computation performed by an individual microcircuit has proved elusive.

The leading proposal for this ‘universal computation’ is Divisive Normalization, which only achieves a FEV (fraction of explainable variance explained) score of 52% in predicting the behavior of neuron populations in the brain. In this project, a Quantum Convolutional Neural Network (QCNN) model is proposed as the canonical computation for a variety of reasons: a) parallel computation is performed by design, b) energetically expensive and time-consuming physical information exchange across neurons is obviated by the entangling nature intrinsic to qubits, and c) higher explainability, parsimony, and applicability to biological systems is achieved via quantum circuit modeling rather than a series of matrix multiplications.

The model was trained and tested using Qiskit on 40x40 images of synthetic and natural stimuli, and the predicted vs. actual firing rates were measured. Further datasets (MNIST, Fashion-MNIST, and Superimposed Noise Datasets) were used to test feature extraction properties and robustness of the model, as well as validate the accuracy.

QCNN consistently outperformed classical models in FEV, making it an attractive candidate for canonical computation.

Autonomous Over-The-Board Chess Solution for Players in Isolated Conditions

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Since the pandemic, online chess has seen unprecedented growth in its user base. This growth is largely due to players being unable to convene physically in quarantine and wanting to play games in isolation. However, a major problem documented in academic research is that players focus less in online chess games compared to over-the-board, physical chess games. The goal of this project was to design a fully autonomous chess board for a single player to play against various levels of computer bots with the ease of online play and the benefits of physical chess.

To achieve this, the team designed and built a 4-string tension system to manipulate the location of an electromagnet. The system utilizes this electromagnet to move the custom 3D printed magnetic pieces from underneath the chess board, all while maintaining the illusion of a normal board. To detect the human player’s moves, the team employed 64 hall effect sensors below the board to detect the presence of a piece on each square. Moves detected by these sensors and Arduino UNO board are then sent to an onboard Raspberry Pi, which sends the optimal response back. The Arduino then instructs the movement system to execute the move.

The three subsystems, movement, sensing, and computing were individually tested to determine their accuracy to ensure total system reliability. From the prototype’s performance and collected data, the team concluded that the project successfully achieved its goal of providing an autonomous over-the-board alternative for a single player.

Utilizing Planarian and Starfish Neural Networks as Cures for Central Nervous System Disorders

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One-billion individuals, one-in-six, suffer from neurological-disorders. Multiple Sclerosis (MS) is an immune-mediated disease of the central nervous system (CNS) where auto-aggressive T-cells cross the blood-brain-barrier (BBB), causing disability. Parkinson's Disease (PD) is a progressive CNS-disorder causing loss of nerve-endings that produce dopamine, leading to movement delays. Alzheimer's Disease (AD) is a CNS disorder with irreversible worsening of memory, destroying neural-pathways. Planarians contain Neoblast Stem-Cells, regenerating when cut; Neoblasts have regenerated a trachea, proving safety/applicability within humans. Starfish contain a protein/gene known as sox2 (allows for regeneration) that is compatible with humans. This study investigates if Neoblasts/Starfish combination can be a cost-effective cure/preventative-measure for neurodegenerative diseases, involving the CNS, compared to current human stem-cell treatments. It was hypothesized that if the combination were given to Earthworms (increasingly similar NS to humans/common CNS model organisms) as cures/preventative-measures, then healthy cells would regenerate while unhealthy cells undergo apoptosis. Experimental groups included negative/positive controls and cure/preventative-measure trials: four-stages MS, five-stages PD, seven-stages AD, respectively. Cell-viability data, calculated using MTT-assay, had all non-control trial groups above 90%; daily activities resumed normally, following combination administration, and cell images indicated reversal of demyelination/degenerated cells. Data indicates that the combination is a potential, affordable cure and preventative measure for CNS conditions (~ $5-$10 for 50 people versus $200,000+ annually of current treatments) due to reparative/specialization (for individual needs) properties that human stem-cells cannot achieve. Current studies examine how to specialize in longevity for different pathogeneses non-CNS disorders.

Virginia

Arachnids as Necrobots and Optimizing Biological Hydraulic Systems

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The robotics industry has long been evolving and innovating, making way for automation and AI to take over a wide variety of tasks. In doing so, countries such as the US with a focus on technological innovation have been able to quickly develop new ideas with little regard to least developed countries (LDCs) without access to those resources. When higher developed countries automate their industries, from architecture to household items, they widen the gap of inequality-driven environmental damage: LDCs are more affected by pollution and climate change. Since the robotics industry uses a very large amount of energy — around 21,000 KWh annually — the gap between the highest developed countries (HDCs) and LDCs widens. In order to close this gap without harming the current robotics industries that benefit the economy and our daily lives, “green” robotics need to be developed and researched further. While this field has been intensively studied in areas of raw energy, as seen by the developments of solar, wind, and other renewable energy sources, it has not been considered in the manufacture of raw materials such as steel, copper, aluminum, and other metals very commonly used in building robots. The simple solution to this issue is biotic materials, or materials sourced from living organisms. This study explores arachnid cadavers as biotic replacements for hydraulic and pneumatic systems as functioning claw robots.

The Effect of Phytotherapies on the Overall Health of Hyperglycemic Induced C. Elegans

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In the context to female diabetes and its association with overall health and infertility, the search for effective treatments led to the coupled use of herbal therapies with western medications. This study investigates the level of efficiency of such remedies and their effect of increasing reproductive and overall health. Moreover, the impact of Ginkgo Biloba, Turmeric, and Shatavari on overall health will be examined through egg and thrash count of wild type and induced hyperglycemic C. elegans. Phyto-therapies were found to be preeminent through an increased thrash count and improvement in the overall health of hyperglycemic C. elegans when compared to wild type C. elegans. A linear regression test was conducted, and results indicated statistical significance ($p<0.05$). Moreover, Gingko Biloba has the strongest impact on increasing overall health and fertility rates in diabetic females. Comparisons between the average thrash count of both C. elegans types after exposure to varying concentrations of Gingko Biloba was done using a linear Regression, indicating statistical significance ($p<0.05$). Shatavari is the expected Phyto-therapy for increasing fertility rates in female diabetes. Moreover, Turmeric was found to be the most effective at increasing egg count at a concentration of 0.001 on hyperglycemic C. elegans. In comparison to Gingko Biloba, which had an average of 4.083 and Shatavari with an average of 8.083. However, additional experimentation is needed to determine the egg count of the control groups and the effect of 0.01 and 0.0001 concentrations on the egg count.

The Effect of Natural Phenolic Compounds on Reducing Oxidative Stress

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Purpose: Oxidative stress is caused by redox dysregulation between free radicals and antioxidants, damaging cellular components. This phenomenon has been implicated in the pathophysiology of various diseases, notably cancer and neurodegenerative conditions, which are becoming more prevalent due to environmental pollutants and unhealthy lifestyle choices. Therefore, the objective of this experiment was to identify a natural phenolic compound exhibiting potency in reducing oxidative stress.

Methods: Cyclic Voltammetry (CV), an electrochemical technique, was utilized to measure the compound's oxidation potential. This experiment employed a conventional three-electrode cell and provided information on the redox behavior of molecules by analyzing anodic peaks of the graph. The observed redox potentials were analyzed versus a Ag/NO_3 reference electrode, serving as a control. It was hypothesized that curcumin would exhibit the smallest oxidation potential.

Results: The results revealed that epigallocatechin gallate (EGCG) was easiest to oxidize and most effective in alleviating oxidative stress. T-tests were conducted and demonstrated that the data was both statistically significant and insignificant. The results did not support the research hypothesis.

Conclusion: It is believed that the results occurred due to structural differences. Curcumin's complex structure and susceptibility to degradation through autoxidation potentially generated pro-oxidant effects. Resveratrol, with two hydroxyl groups and a less-intricate conjugation system than curcumin, demonstrates greater effectiveness. In contrast, cinnamic acid has a small and simple structure, contributing to its lower oxidation potential than resveratrol. Finally, EGCG's significant impact on mitigating oxidative stress is attributed to its moderate conjugation system and more functional groups with electron-donating capabilities.

The Effect of the Duration of Pacifier Usage on Speech Development

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Effective communication is crucial for navigating life, and speech-sound development plays a pivotal role in establishing communication skills. Communication disorders, affecting 5-10% of all children in the United States, encompass impairments in speech, language, and hearing. Speech pathology, a field focused on communication science and disorders, is instrumental in diagnosing and treating these disorders. Previous research has linked non-nutritive sucking habits, such as pacifier usage, to speech development delays. Pacifier usage has been associated with altered tongue and teeth positioning, leading to malocclusion, and diminished auditory input, potentially affecting speech comprehension and pronunciation. This study explores the impact of the duration of pacifier usage on speech development in children ages six and seven. Speech screenings were conducted with first and second graders at elementary schools to assess the number of phonemes (speech sounds) they could accurately say. Parents were surveyed regarding pacifier usage history, and participants were assigned numbers for anonymity. The screenings involved presenting pictures targeting specific phonemes, with students pronouncing phonemes displayed on the page. The number of phoneme pronunciation errors were tallied for analysis. Results indicate that 85% of six-year-olds and 60% of seven-year-olds in the sample used pacifiers. The average number of phoneme errors increases with the duration of pacifier usage, with the highest average (9.3 errors) observed in children using pacifiers for over 36 months. A linear regression test resulted in a highly significant P-Value less than 0.01, suggesting a significant correlation between longer pacifier usage and increased phoneme errors.

Equivariant Graph Attention Networks with Structural Motifs for Predicting Cell Line-Specific Synergistic Drug Combinations

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Cancer is the second leading cause of death, behind heart disease, with chemotherapy as one of the primary forms of treatment. As a result, researchers are turning to drug combination therapy. However, current methods of screening such as in vivo and in vitro are inefficient due to time and monetary costs. In silico methods have become increasingly important, but current methods of screening drug combinations are inaccurate and generalize poorly. In this paper, I employ a geometric deep-learning model based on a rotational and translation equivariant graph attention network with structural motifs. Additionally, the gene expression of the cancer cell line is used as an input to a multi-layer perception to classify the synergistic drug combinations based on each cancer cell line. I compared the proposed geometric deep learning framework to state-of-the-art methods and achieved greater performances on all 12 benchmark tasks performed on the DrugComb dataset. Specifically, the proposed framework performs superior to other state-of-the-art methods by greater than an accuracy of 28%. Based on these results, I believe that the equivariant graph attention network's capabilities of learning geometric data account for large performance improvements. The model's ability to generalize to foreign drugs is thought to be due to the structural motifs better representing the molecule. Overall, I believe that the proposed equivariant geometric deep-learning framework is an effective tool for virtually screening anticancer drug combinations for further validation in a wet lab environment.

Virtual

Specific Inhibition of Mitochondrial Glycerol 3-Phosphate

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Mitochondrial glycerol 3-phosphate dehydrogenase (mGPD) is on the outside of the inner mitochondrial membrane and catalyzes the reaction turning glycerol 3-phosphate (G3P) into dihydroxyacetone phosphate (DHAP), which reduces NADH into NAD+, 2 electrons, and a hydrogen proton. mGPD adds electrons and protons into the matrix, causing a proton motive force collapse in the electron transport chain. This leads to the formation of reactive oxygen species (ROS), which damages metabolic processes. Therefore, inhibiting mGPD prevents the formation of ROS. My project investigated the most probable pharmacophore of a compatible inhibitor for mGPD. By using a machine learning model, trained with enzyme recognition and ~1400 substrates, the compatibility of various substrates with mGPD was calculated. I hypothesized that an inhibitor with multiple guanidine groups may be effective for binding to mGPD because metformin is a biguanide. Additionally, I hypothesized that increasing structural similarity to G3P, the original substrate, would lead to increasing binding compatibility. I ran a collection of substrates, varying numbers of guanidine groups, and structural similarity to G3P, through the machine learning model. The program outputs a score of 0-1, where a score closer to 1 suggests higher compatibility. The data shows no strong association between an increasing number of guanidine groups or structural similarity to G3P and binding compatibility with mGPD. However, results suggest that the phosphate group may be an important feature of the final inhibitor to demonstrate.

A Comprehensive LC-MS Metabolomics Approach Reveals a Novel Panel of Markers in an APOE4 Mouse Model of Alzheimer’s Disease

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APOE is a mediator of lipid metabolism and allele APOE4 is the strongest genetic risk factor for Alzheimer's disease. One copy of the allele increases likelihood for Alzheimer's by three-fold while possessing two-copies of the allele increases the chances by up to 15-fold. However, the effects of APOE4 on the human brain are not fully understood, limiting opportunities to develop preventative therapeutics for carriers. To gain insight on the molecular impact of APOE4 over time, liquid chromatography-mass spectrometry (LC-MS) untargeted metabolomics analysis of cerebellum tissue samples at 6, 12, 18, and 21 months from both E3 and E4 mice was conducted and analyzed. Results have identified four downregulated and one upregulated metabolic marker at 21 months, which provide evidence in support of APOE4 as an inhibitor of normal function. Furthermore, metabolic profiles across the mouse life span as well between males and females at each time point was compared to assess the molecular changes caused by APOE4 and gain further insight into the mechanism by which the allele increases susceptibility for Alzheimer’s disease.

Empathy and Trust as Key Drivers of Patient Satisfaction in Healthcare

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This study examines the effects of trust in the patient-doctor relationship and the physician's empathetic approach on patient satisfaction. It proposes two hypotheses: first, there is a direct positive relationship between patients' trust in their doctors and their satisfaction levels; second, a doctor's empathetic behavior is crucial in mediating the relationship between trust and satisfaction. A survey of two hundred fifty U.S. patients, utilizing established measurement scales, revealed a significant positive correlation between patient-doctor trust and patient satisfaction. Interestingly, empathy was identified as a key factor that

reinforces the positive impact of trust on satisfaction, serving as a mediating variable. These findings indicate that patient satisfaction extends beyond clinical outcomes, highlighting the significance of empathetic practices in healthcare to enhance patient-doctor interactions. Consequently, healthcare practitioners are encouraged to focus on building trust and integrating empathy into their care practices to enhance the quality of service. This study advocates for an innovative healthcare approach that combines empathetic care with clinical expertise, catering to the changing expectations of patients in the healthcare sector.

Circulating Chymase and Chronic Kidney Disease: An Analysis of Current Treatments, Demographics, and Clinical Risk Factors

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Chronic kidney disease (CKD) results in a progressive loss of kidney function over time, affecting 37 million in the US. Chymase is the primary enzyme mediating angiotensin II formation independent of the angiotensin-converting enzyme, potentially causing renal fibrosis. This novel study investigated differences in chymase levels between CKD-affected populations and non-CKD-affected populations while adjusting for potential confounding of current treatment, clinical risk factors, and medical history. Population was organized into two groups in New Orleans: participants diagnosed with CKD (n=163) and the control group, participants not diagnosed with CKD (n=186). Three models were created to measure differences in median chymase levels between the two groups while adjusting for common CKD risk factors and treatments. Medians and interquartile ranges for plasma chymase were calculated for both groups, and Mann-Whitney U tests determined differences in the unadjusted medians. Quantile regression was used to create the three models and obtain multivariable-adjusted medians for plasma chymase levels in both groups. Wald tests assessed differences in adjusted medians between the two groups for all three models. After adjustment for all variables tested, median plasma chymase remained significantly higher (p=0.04) in CKD patients (1.7 pg/mL) compared to controls (1.2 pg/mL). This study established an association between elevated chymase levels and CKD, independent of all factors studied. Results provide the foundation for vital further research determining if chymase is a viable measure to predict CKD progression and assessing effectiveness of chymase inhibitors in improving renal outcomes for CKD patients.

High-Resolution Super sampling of BASP-ORCA Contrast Agents in Magnetic Resonance Imaging

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Magnetic Resonance Imaging (MRI) is crucial in clinical diagnostics, but traditional metal-based contrast agents have toxicity concerns. When nearly 1 in 7 Americans suffer from some class of Chronic Kidney Disease traditional contrast agents pose a risk to their health due to heavy metal toxicity. Brush-Arm Star Polymer Organic Radical Contrast Agents (BASP-ORCAs), a new metal-free class, enhance MRI by providing better transverse relaxivity and stability, reducing health risks from conventional agents. The research evaluates deep learning models, specifically convolutional neural networks and hybrid attention transformers, for improving MRI scan resolution. These models are trained on nearly three hundred T1 and T2 MRI images, mainly sourced from the IXI dataset and supplemented with BASP-ORCA scans. Images are downscaled so that they can be trained against their high resolution counter parts. The models are meant to learn complex patterns to enhance image quality. This results in sharper, more detailed images, crucial for tumor detection and characterization. The model achieved a Structural Similarity Index Measure of 0.92 and a Peak Signal-to-Noise Ratio of 33.13, showing its effectiveness. Combining BASP-ORCAs with advanced computational techniques could improve diagnostic accuracy and patient safety, signifying a shift towards non-toxic radiology solutions.

Washington

A Computer Vision Based System to Make Street Crossings Safer for the Visually Impaired

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Crosswalks are dangerous places with high risks of pedestrians coming into contact with cars. Unfortunately, this problem is especially true for visually impaired pedestrians, as they cannot see when a distracted driver drives past the red light, potentially causing them a fatal injury. Computer based solutions to make crosswalks safer focus more on detecting if the crosswalk sign is on and making sure the user knows the path to the other side of the street. However, these solutions do not take into account that a distracted driver might run past the red light and potentially cause any injury to the user. We aim to create a system that uses a camera stream and detects if there are any incoming vehicles while a visually impaired user is crossing a crosswalk and notifies them of any potential hazards. This system detects the vehicles using object detection and tracks their distance to the user using depth detection. Our system is embedded on a Raspberry Pi and an Intel Neural Compute Stick 2. The models and logic are tested against real world data collected from neighborhoods around Seattle, Washington. The results indicate a high precision of 96%, which allows for continuous advancement and deployment in future research.

Design and Evaluation of a Trap for Tracking the Settling Preferences of Adolescent Crabs

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Mentor: Ron Nilsen, Bellarmine Preparatory School

The purpose of this study was to design a trap that would be used to track whether or not crabs during their megalopa stage had a settlement preference. Knowing their settlement preferences helps allow population tracking, as crabs are a keystone species and have a large role in the fishing industry in this region. This was tested at Titlow Marine Preserve, making this different from past research as it is open water rather than being in a contained and controlled environment. We hypothesized that the larger rocks would provide a more suitable shelter as they are more stable. We placed 3 bins, each with a different substrate, into the Marine Preserve, and collected them after a few weeks. We would then collect the species found and analyze this data. We found that the vast majority of micro-species (all belonging to the Arthropoda phylum) preferred to settle in the cobbles, followed by the large rocks, with few preferring the sand substrate. We found that the larger species tended to vary more, with the large rocks bins containing more larger species than any of the others. These results can be used for future studies as a baseline that shows the settlement preferences of Arthropods, which could be used to track populations.

LeAF: Leveraging Convolutional Neural Networks for Plant Anomaly Detection and Classification for Farmers with Large Language Models for Natural Language Interaction

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Farmers face numerous challenges in crop cultivation, particularly in monitoring and maintaining plant health. Plant anomalies such as pests, diseases, and weeds are critical indicators of poor plant health, leading to decreased crop yield. Over 40% of global crop production is lost to plant anomalies, costing $220 billion annually. As global food demand rises, manual surveillance for plant anomalies becomes increasingly difficult, resulting in excessive and indiscriminate use of fertilizers and pesticides. This not only escalates costs but also heightens environmental/consumer concerns due to chemical runoff, emissions, and residues. The lack of data on plant anomalies further compounds the issue, leaving farmers unaware of the efficacy of their practices. Leveraging recent advancements in multimodal Artificial Intelligence (AI) with Convolutional Neural Networks (CNNs) and Large Language Models (LLMs), I propose LeAF - a

comprehensive system to survey crops in real-time. LeAF aims to achieve six objectives: (1) utilizing CNNs to analyze robot camera feeds for plant anomalies with bounding box detection and classification, (2) employing plant stem identification to attribute anomaly data to specific plants and create field maps, (3) integrating a domain-specific LLM to provide farmers with optimal treatment suggestions, (4) supporting question-answering on farming techniques, (5) offering estimates on strategy-effectiveness, cost-savings, and environmental impact reduction, and (6) deploying a custom-made BRANCH robot (Budget-friendly Robot for Agricultural Nonintrusive Crop Photography) at local farms that costs under $500. This end-to-end solution addresses the challenges faced by farmers, empowering them with actionable insights to enhance crop management efficiency while minimizing environmental impact.

Serum Bilirubin Prediction for Neonates using Segmentation-Guided Neural Networks

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Across the world, millions of newborns suffer from severe neonatal jaundice, a condition that can cause neurological damage and death. Approaches such as laboratory blood tests and transcutaneous bilirubinometers for assessing jaundice are financially inaccessible in developing countries, and current computer vision approaches suffer from ease-of-use issues. Furthermore, spectroscopy-based devices produce inaccurate total serum bilirubin (TSB) estimates for neonates with darker skin tones. This research develops novel multi-stage deep learning models to predict bilirubin levels from smartphone imagery of blood plasma test strips. The first task involved training a segmentation model to segment the region of extracted bilirubin from the test strips. In the second task, color and environmental features from the segments are calculated as inputs into a deep regression neural network to predict TSB. The machine learning models are integrated into an end-to-end mobile application for real-world clinical use. The results indicate the segmentation model can adapt to rotational, scale, and ambient lighting irregularities in blood-based bilirubin extraction test strips and successfully segment regions with high bilirubin concentration. The second neural network predicts TSB levels that strongly correlate with state-of-art laboratory measurements (cross-validated Pearson R = 0.83). The mobile application provides bilirubin predictions with an error of 2.38 mg/dL in under five seconds. BiliNet offers significant ease-of-use advancements due to the use of inherently skin-tone agnostic blood plasma test strips. The strong clinical relevance is demonstrated by using predicted TSB to classify whether a neonate requires phototherapy with 95% accuracy. The inexpensive (<$1) system can enable widespread proliferation of neonatal jaundice screening in low-middle income countries and reduce fatalities.

Simulated Thermal Dataset for Training Wildlife Monitoring Models with Optical to Thermal Domain Transfer - A Case Study on the I-90 Snoqualmie Pass East Project

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COCOTherm addresses the challenges of monitoring wildlife overpasses as part of the I-90 Snoqualmie Pass East Project. The wildlife monitoring program for this project involves 15 networked motion-activated thermal cameras, generating over two million images and videos annually. Classifying this data currently requires a dedicated full-time biologist, which is unfeasible at scale. The lack of automation is attributed to the absence of effective computer vision models for thermal imagery, a challenge stemming from the limited availability of annotated thermal data.

The proposed solution is the creation of a morphing pipeline to convert large datasets of annotated optical imagery to thermal imagery, which is novel in the field of computer vision. This pipeline can make thermal image datasets without having access to any real thermal data. By simulating thermal data, small thermal datasets will never be an issue in the training of accurate thermal models, making the idea of effective automated animal monitoring possible. Spanning 11 classes of animals across 27,000 images, the thermal

data set generated as part of this research is the most comprehensive and largest thermal animal data set in the public domain.

The model trained on this simulated thermal data achieved a recall of 97.65% on real-world animal crossing data from the I-90 corridor and a precision of 100%, meaning there were no false positives, which solves the biggest problem on the overpasses. The model is currently being deployed for cameras on two overcrossings and will be scaled to 12 other I-90 overcrossings/underpasses incrementally.

West Virginia

Reach Into the Mind: An Engineering Project and Study of the Human Brain and its Application to Brain-Computer Interface (Year 2)

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Teacher: Lisa Berry, Parkersburg High School

Brain-Computer Interface or BCI is beginning to become prevalent in modern-day technology. This includes Electroencephalogram headsets, Elon Musk's Neuralink, etc. However, this new technology has not been translated to the modern-day person. This is exactly what our project sets out to do. In our project, we used an Electroencephalogram (EEG) headset to control a robotic arm that we self-engineered. This basis showed us that creating BCI is feasible. Expanding into year two, we created a new, more efficient arm. Pairing this up with a precise 4-channel EEG headset provided us with detailed readings to use with the BCI. The new arm we created is much larger and implements multiple pully drives that increase torque providing a variety of uses. The robotic arm operates through 5 degrees of freedom with a claw at the end. With this new arm, we have expanded the potential of our project. Advancing the accuracy and time efficiency of our robotic arm is the final step we completed before implementing the code to make it seamless. Using Machine Learning, we will adapt the headset to the individual user, allowing anyone in the world to use it seamlessly without the need for manual parameter adjustments.

Bridging the Gap using EdTech and AI

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"Bridging the Gap using EdTech and AI" includes (1) an original implementation of a new EdTech desktop application and an iOS mobile app and (2) a multilingual international application of an artificial intelligence (AI) teaching pedagogy. My EdTech app was used to educate learners across different learning levels by adjusting the proficiency level of content in English and translating the same content into Português. Six teachers from two counties/three cities in West Virginia, and two from Brazil were recruited to protype EdTech, which I developed a desktop and iOS mobile app for. The personalized learning model can change (1) how knowledge is engaged in the classroom, (2) the complexity or addition of multiple subjects in the content of classes, and (3) to add cultural integration, while educating students who are at different learning levels. My study used paired t tests to assess the proficiency of student learning using posttest averages. I measured increased change in language proficiency. The hypothesis was: 70% of students will score a 75^+ on posttests modified using AI and posttest averages will show positive change in students' learning proficiency to determine the usefulness of the EdTech App. A score of 75% or above was considered proficient. To measure proficiency, the study assessed whether posttest scores showed a change in students' learning proficiency of information represented on only the questions from the pre-test. The data supported the hypothesis: 40/99 students (40%) scored a 75^+ on the pretest and 72/99 (73%) scored 75^+ on the posttest.

Injective Chromatic Index of Packet Radio Networks: Improved Upper Bounds

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This project focuses on Packet Radio Networks (PRN), represented as a graph G = (V,E) with V and E as its vertex and edge sets respectively. The vertices represent the set of stations, and two vertices are joined by an edge if the corresponding stations can hear each other's transmissions.

The primary objective is to determine the injective chromatic index of PRNs, a measure that involves assigning frequencies to edges to prevent secondary interference which occurs when stations sharing a frequency with their respective neighbors experience interference. We would like to decrease this to maximize the efficiency of the PRN. This concept, introduced in 2015, presents an optimization problem: determining the minimum number of frequencies required for a given PRN G=(V,E) – the injective chromatic index of G.

The challenge lies in the computational complexity of pinpointing the exact injective chromatic indices. In this project, using the coloring extension and the discharging methods, I improve existing upper bounds of injective chromatic indices of sparse graphs with small maximum degrees. Additionally, I extend these improvements to sparse graphs with arbitrary maximum degrees. Notably, I rectify an incomplete proof from prior research, providing a validated proof for the result in question. The findings contribute to advancing our understanding of injective chromatic indices, with potential applications in more efficient channel assignments in Packet Radio Networks.

Two-Step X-Ray Transit Identification: Bayesian Block Simplification and Sequential Machine Learning Techniques

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The transit method is versatile; it has been critical in not only the discovery of over four thousand Milky Way exoplanets but also the impressive discovery in galaxy Messier 51 of M51-ULS-1b, the first possible extragalactic planet. However, current methods of detecting transits involve visual identification, take significant time, and can be prone to human error. Combined with the large amount of data available, these observations naturally point to the use of computational techniques to aid the transit method. In this work, a two-step development of a machine-learning model was proposed to automate transit identification. In the first step, a simplified light curve was generated using the Bayesian blocks algorithm. Then, time-series datasets containing sections of event lists (sorted depending on the presence of a transit) were created. A training dataset was created from a source in 47 Tucanae containing many example transits; a validation dataset was created from the transit of M51-ULS-1b as a prime example of an extragalactic planet. In the second step, a random forest model was trained, optimized, and evaluated: it performed with high accuracy and was able to find the exact point in time of the transit for M51-ULS-1b. This method is unique because of its efficiency and applicability: it significantly focuses the approach to transit identification by reducing the time (from days to minutes) and possible errors involved in finding statistically significant transits and also allows astrophysicists to perform meaningful work without the need for an “intuition.”

They Don't Know When to Quit: Investigating "Overharvesting" in a Simulated Berry-Picking Experiment

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From assessing mammograms to finding lost keys, visual searches are ubiquitous. This study employs a berry-picking scenario to study the effect of external distractions on optimal decision-making. In our model, berries are harvested at various different patches, and movement between patches involves a "travel time" during which no berries may be picked. Previous research on similar visual foraging tasks has supported the marginal value theorem (MVT), stating that individuals generally move from one patch to another when their instantaneous rate of picking drops below the overall rate. However, our unique investigation included a multiple item tracking (MIT) distraction during the travel time between patches, and as a result participants were observed to spend longer than optimal time in the patch — deviating from MVT predictions. The observed overharvesting was hypothesized to result from the participants' lack of awareness of their real-time "current" overall rate. Though patch leaving behavior is governed by the overall rate as stated by the MVT, this rate can only be calculated once the experiment concludes. To rectify this, a "current" overall rate was calculated and updated by click for comparison with the instantaneous rate. Data analysis showed a decrease in overharvesting when comparing instantaneous rates with a by-click updated "current" overall rate rather than the overall rate calculated post-experiment. Despite these improvements, a definitive underlying cause remains yet to be determined. Regardless, these findings provide valuable insight into patch leaving behavior — applicable to not only berry patches but also medical scan analysis, resource management, and more.

Wisconsin/Upper Peninsula Michigan

Reverse Transcriptase-Polymerase Chain Reaction Testing of *Aedes triseriatus* mosquitoes for Detection of La Crosse Virus in La Crosse County, Wisconsin

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Aedes triseriatus is a tree-hole dwelling mosquito native to the United States and one of the most common species in La Crosse County, Wisconsin. *A. triseriatus* mosquitoes are the primary vector of La Crosse virus (LACV). *A. triseriatus* have maintained LACV in nature through animal hosts, including small mammals, but also contract LACV from each other through horizontal and vertical transmission. The first case of La Crosse encephalitis, a mosquito borne illness caused by LACV, was detected in La Crosse County during the year of 1960. La Crosse encephalitis cases were most prevalent in the upper Midwestern region of the United States until the mid-2000s but are now more frequently seen in the Appalachian (Southeastern) region of the United States. This study used Reverse Transcriptase-Polymerase Chain Reaction (RT-PCR) to test *A. triseriatus* mosquitoes in La Crosse County, WI to determine the presence and prevalence of LACV. Interestingly, all of the *A. triseriatus* mosquitoes collected in La Crosse County during the summer of 2021 tested negative for LACV. This prompts further hypothesis analysis to identify the reason behind the fall of La Crosse encephalitis cases.

Optimizing Dye-Sensitized Solar Cell Efficiency: The Effect of Light Intensity on Energy Absorption in Organic Dyes

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Dye-sensitized solar cells (DSSCs) offer solutions to drawbacks of traditional silicon solar cells. However, research is needed to identify and harness factors that may increase their efficiencies to match or surpass silicon solar cells. Published DSSC research focuses on testing static plant factors, including pigment or plant type. No prior research has manipulated the conditions plants were grown under or experimented with plant acclimation. This research aims to determine if DSSC power efficiency can be increased using dyes extracted from plants acclimated to low-light conditions. When moved to low-light conditions, many plants acclimate to produce more pigments or optimize their photosystem ratios. It was hypothesized that these plants will absorb light more efficiently as a dye in a DSSC. Spathiphyllum plants were exposed to low light conditions for increments of 12 hours (0 - 84 hours) and extracted as dyes for 8 DSSC experimental groups. DSSCs were constructed, and power was measured over time using a multimeter. Results identified optimal acclimation period as 72 hours under low light conditions prior to extraction. Subsequent testing with a larger sample size found a 13% average increase in power from the 0 hour to 72 hour groups. This supports the hypothesis and suggests Spathiphyllum may acclimate to suboptimal light conditions, enabling increased absorption as a dye. This study reveals plant acclimation may be harnessed in DSSCs to boost power output. There are numerous applications of this research to synthetically modify dyes mimicking acclimating structures, critical to increase the efficiency and viability of DSSCs.

Characterization of Antimicrobials from the Soil Bacterium *Xenorhabdus szentirmaii*

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Antimicrobial resistance is a global health threat, and the discovery of new antimicrobial compounds have been limited in the past three decades. A potential source of new antimicrobials is the soil bacterium *Xenorhabdus szentirmaii*, a symbiont of nematodes that invade the insect larvae. The nematodes regurgitate the bacterium, which kills the insect larvae by releasing toxins and antimicrobials. This allows the nematodes to extract nutrients from the larvae. From cell-free cultures of *Xenorhabdus szentirmaii*, we established a protocol to separate antimicrobials into three distinct soluble forms: two in methanol and one in dimethyl sulfoxide (DMSO). Further separation of antimicrobial compounds by high-performance-liquid-chromatography (HPLC) followed by mass spectrometry revealed new isoforms of fabclavine (peptide-polyketide antibiotic) within the methanol-soluble antimicrobials and a lipopeptide compound in the DMSO-soluble antimicrobials.

The antimicrobials of *Xenorhabdus* species are primarily produced by non-ribosomal peptide synthetases (NRPS) and polyketide synthetase (PKS) genes. A genome analysis revealed that *X. szentirmaii* contains 15 NRPS gene clusters and one hybrid NRPS-PKS gene. Mutation of the putative fabclavine biosynthetic gene encoded by the hybrid NRPS-PKS gene showed a reduction in the ability to inhibit both bacterial and fungal growth. In summary, our results substantiate the potential of *Xenorhabdus szentirmaii* as a promising natural source for future antimicrobial discoveries.

An Auxiliary Rehabilitation Device for Patients with Muscle Tremors

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Patients coping with conditions such as Parkinson's often face challenges with irregular tremors and finger stiffness, resulting in diminished normal finger functionality. Research underscores the potential advantages of integrating medication therapy with rehabilitation device training for finger joints, playing a crucial role in restoring active mobility by facilitating passive finger movement and enhancing flexibility. This

auxiliary rehabilitation device undergoes in-depth research on pneumatic-driven Extensible Pneumatic Muscles. The relays and air pumps are precisely controlled by an Arduino board, effectively managing the inflation and deflation of the Extensible Pneumatic Muscles system in each finger. This capability actively guides finger flexion and extension during rehabilitation training. The maximum flexion angle of the device can reach 70 degrees, with a deviation of less than +/-10%. Additionally, the rehabilitation device assesses the recovery status by analyzing the maximum flexion angle changes in the patient's self-training finger movements over a period of time. Equipped with an accelerometer, it aids in scale rating the tremors associated with Parkinson's fingers, enabling at-home monitoring. The device further extends its functionality to life assistance, commonly utilized to prevent inadvertent actions by restraining fingers affected by tremors from unintentionally clicking the mouse during movement. This design incorporates a mobile app, allowing users to effortlessly and swiftly connect to rehabilitation equipment. It leverages the portability of both mobile phones and rehabilitation equipment, enhancing convenience of the device.

A Neural Network Approach Using Deep Learning for Image Classification of Polar Ring Galaxies

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Understanding the formation of peculiar galaxies, such as polar ring galaxies, can aid in learning the properties of dark matter and the process of deciphering how galaxies evolved. A polar ring galaxy is a type of galaxy with a ring of gas and star matter orbiting over the perpendicular plane of its host galaxy. Less than 1% of all galaxies are polar ring galaxies, making their data very limited. Manual classification of these galaxies can take months to years, and the human error rate is high. For this reason, polar ring galaxies have not been the focus of astronomical research. We present a method to classify polar ring galaxies using a convolutional neural network (CNN). Multiclass classification was utilized, where the categories are smooth galaxies, disk galaxies, and polar ring galaxies. A CNN was trained on polar ring and non-polar ring data and then tested on a real unclassified dataset of 7,840 NGC (New General Catalog) galaxies. Four polar ring galaxies, 426 smooth galaxies, and 412 disk galaxies were extracted from this previously unclassified dataset at a rate of 130 galaxies per minute. As upcoming sky surveys continue to be released—such as the WALLABY sky survey, which will contain candidates for polar ring galaxies—machine learning models such as the one we propose could be tremendously useful to better understand the mechanisms by which a plethora of galaxies form.

Wyoming and Colorado

National Ground-Level NO_2 Predictions via Satellite Imagery Driven Hybrid Neural Networks

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Outdoor air pollution, specifically nitrogen dioxide (NO_2), poses a global health risk. Land use regression (LUR) models are widely used to estimate ground-level NO_2 concentrations by describing the satellite land use characteristics of a given location using buffer distance averages of variables. However, information may be leaked in this approach. Therefore, in this study, I leverage a convolutional neural network (CNN) architecture to directly pass pixel plots of satellite imagery for the prediction of U.S. national ground-level NO_2. I designed CNN architectures of various complexity which inputs both image and numerical based data, testing both high and low resolution pixel plots. My resulting model accurately predicted NO_2 concentrations at both daily (R^2 = 0.898) and annual (R^2 = 0.964) temporal scales, with coarse resolution imagery and simple CNN architectures displaying the best and most efficient performance. Furthermore, the CNN outperforms traditional buffer distance models, including random forest (RF) and neural network approaches. Additionally, with a novel graph neural network (GNN) based approach which leverages network interactions between monitoring sites, I developed a hybrid hierarchical GNN-CNN model which captures both short and long-distance associations between monitors. The resulting hybrid model

significantly improved prediction against new and unseen monitors. With the success of hybrid neural networks in this approach, satellite land use variables continue to be useful for the prediction of NO_2. Using this computationally inexpensive model, I encourage the globalization of advanced LUR models as a low-cost alternative to traditional NO_2 monitoring.

Characterizing a Novel Flare in the Distant Quasar VIIIZw233

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The universe is filled with turbulent events, from the collision of black holes to the death of a star in an explosive supernova. One such event is a Tidal Disruption Event (TDE), where a star approaches a black hole and is ripped apart by the black hole's gravitational forces. The material from the star deposited in the accretion disk causes increased activity in the galaxy. Stellar matter orbits the black hole in an accretion disk. The resulting friction of these fast-moving objects is output as light which is called a quasar. VIIIZw233 is a quasar and is located 1.7 billion lightyears from Earth. In 2018, an unusual flare was documented by the Wyoming Infrared Observatory as electromagnetic spectra. This study's objective was to categorize the flare in VIIIZw233 and compare them to characteristics of other flares. It was hypothesized that the characteristics of the flare will be similar to a TDE. All data were analyzed in Google Colab, a platform for executing Python online. The values obtained for the peak luminosity, the shapes of the continuum and Hβ light curves, the emission lines in the difference spectra, and the color of the object were comparable to other TDEs.

Determining Whether the Protein Tyrosine Phosphatase Non-Receptor Type 2 (PTPN2) Gene Plays a Role in the Development of Type 1 Diabetes

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Type 1 diabetes (T1D) is an autoimmune disease that leads to destruction of insulin producing β-cells. It is unknown what causes the disease and there's no lasting cure. The protein tyrosine phosphatase non-receptor type2 (PTPN2) gene may play an important role in the disease. Mutations in the gene are often associated with increased risk of TID development. However, it is unclear what role PTPN2 plays in regulating antibody producing B-cells, and how it subsequently affects immune regulation. If PTPN2 plays a role in regulating B-cell antibody production, it was hypothesized that antibody production will increase if PTPN2 is deleted. Our study explores how PTPN2 deletion affects total IgG and IgG isotype antibody production in B-cells using the enzyme linked immunosorbent assay (ELISA). Our experiments compared the antibody levels of mice with PTPN2 knockout/deletion (PTPN2-KO) in their B-cells and control/wild-type (WT) mice with normal PTPN2 expression. There was, on average, a 48.332% increase in total IgG antibodies in PTPN2-KOs compared to WTs. There was also a trend towards increase in IgG isotypes: IgG1, IgG2a, IgG2b with percent increases of 30.17%, 11.459% and 16.23% respectively in PTPN2-KO mice. There wasn't a significant change in IgG3 antibody levels. The increase in total IgG antibodies was proven statistically significant. These results suggest that PTPN2 in B-cells plays an important role in regulating total IgG antibody production and its deletion may contribute to the development of T1D. This finding may help in developing gene therapy as a T1D solution.

Enhancing Dry Cooling in Power Plants through High-Conductivity Thermal Ground Planes

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As global electricity demand increases, the majority of power is produced by thermoelectric plants using fossil and nuclear fuels, despite the rising role of renewables like solar and wind. These plants typically dissipate about 60% of generated heat, often through water cooling, which poses sustainability issues due to significant water usage. With ongoing water shortages, there's a shift towards alternative dry cooling methods that use air, but these methods face efficiency challenges due to air's lower thermal properties. This study introduces high thermal conductivity thermal ground planes (TGPs) as fins in dry cooling systems to overcome these challenges. TGPs, encapsulating a phase-change material, exhibit thermal conductivities tens to hundreds of times higher than metals, leading to rapid heat dissipation. My experimental results show TGPs achieving effective thermal conductivities up to 30,000 W/mK, significantly outperforming traditional aluminum fins. Simulating TGPs in a 600 MW power plant's dry cooling system indicated a 2.5°C reduction in turbine discharge temperature, a 0.8% efficiency increase, 1% lower coal consumption, and fuel cost savings of approximately $500,000 annually for the power plant. This approach not only reduces water dependency, but also enhances dry cooling efficiency and operational costs in power plants.

Refil: A Novel Closed-Loop Materials Flow for Low-Cost and Efficient Sustainable 3D Printing Filament Recycling

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Polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) are the two most common materials used in three-dimensional (3D) printing, a rapidly expanding industry currently valued at $17.4B. Unfortunately, PLA and ABS are classified as Type 7/“Other” plastic, and thus cannot be recycled by conventional means. Moreover, due to a waste rate of ~30-50% in the 3D printing industry, thousands of tons of 3D-printed materials are discarded annually. In this project, we developed a novel, cost-effective, and environmentally friendly closed-loop solution to scalably recycle these plastics. First, we evaluated the densities, tensile properties, impact strength, and melt flow indices of more than ten different types of 3D-printed PLA and ABS waste materials, as well as their mixtures. We then designed a density-based separation process that leverages an inexpensive, readily available, and non-toxic sodium chloride (NaCl) solution to separate PLA and ABS in the waste mixture. Ultimately, we developed a method to extrude and regenerate high-quality 3D printing filament consisting of 100% recycled PLA and ABS (rPLA and rABS). While the individual extrusion processes for recycled PLA and ABS were unsuccessful in producing high-quality 3D printing filament due to issues such as moisture bubbles, inconsistent thickness, and brittleness, a specific PLA to ABS extrusion ratio yielded high-quality, smooth, and printable filament. Our recycling method is both environmentally friendly and cost-effective, providing significant advantages over the currently prevalent chemical recycling methods that are capital-intensive and pollution-generating, as well as the practice of using a high percentage of virgin materials (>30%).