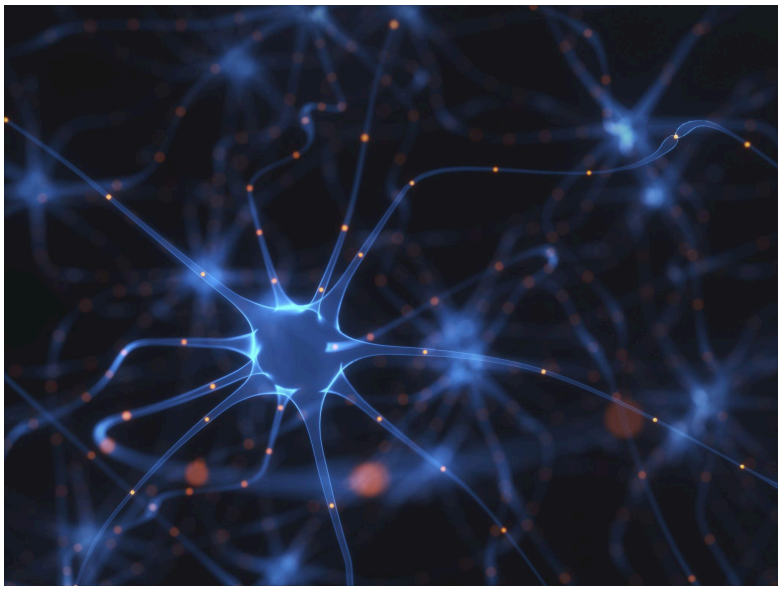

NJIT New Jersey Institute of Technology

2024 BOOK OF ABSTRACTS

2024 UNDERGRADUATE SUMMER RESEARCH AND INNOVATION SYMPOSIUM

JULY 24-25, 2024

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An Experimental and Modelling Approach for Optimizing Bioink Formulations for 3D Bone Bioprinting

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Abstract: Osteoporosis is the most common bone disease – affecting over 10 million people in the United States according to the Centers for the Disease Control and Prevention (CDC). There is a growing demand to develop patient-specific and highly adaptable bone graft alternatives to cure large bone defects. This research project aims to use 3D bioprinting to fabricate bone scaffolds from methacrylated alginate (MeAlg) supported with tricalcium phosphate (TCP) or human bone particles (hBPs). Alginate, a biopolymer derived from brown seaweed, is widely used in bioprinting. TCP is a calcium salt of phosphoric acid, which is known to support bone regeneration. The hBPs have inherent bioactivity to enhance bone formation. The focus is on evaluating various bioink compositions by altering the concentrations of MeAlg, TCP, and hBPs. By conducting comprehensive rheological and mechanical tests, this study seeks to predict bioink performance and end-use properties, including cell proliferation and differentiation. The ultimate goal is to determine which bioink formulation optimally supports stem-cell behavior, enhancing the efficacy of the resulting scaffolds for bone tissue engineering. The expected outcome is to develop a model that optimizes bioink development, contributing to advancements in bone tissue engineering and regenerative medicine.

Role of Matrix Metalloproteinase-12 in Inducing Caspase-3 Regulated Apoptosis Following Repetitive Low-Level Blast Traumatic Brain Injury

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Abstract: Approximately 64 to 74 million individuals worldwide suffer from a traumatic brain injury (TBI) every year. A traumatic brain injury is defined as any sudden brain injury caused by blunt force, rapid acceleration/deceleration, or blast overpressure, causing symptoms such as dizziness, memory lapses, and mood disorders. Blast injuries, in particular, are caused by exposure to explosives, transmitting a wave of air pressure from the explosion site to the brain, causing rapid acceleration and compression/decompression. Although many studies have been conducted regarding the effects of high-level blast injuries, many military personnel experience repetitive, low-level blasts, whose effects have not been as thoroughly investigated. Caspase-3, an enzyme involved in apoptosis following the breakdown of cellular proteins, has proven to be a significant biomarker in detecting central nervous system damage following strokes and high-level blast exposure. The goal of this research is to identify the prevalence of Caspase-3 following exposure to repetitive low-level blasts, allowing for therapeutic treatments following high-level blasts and strokes to be utilized following repetitive low-level blasts as well. Due to the resemblance of rodent brains to human brains, rodents were utilized as a model for the experiment and were exposed to five blasts of 70 kPa each, which is categorized as a low-level blast. Following blast exposure, the rodents performed memory and motor function tests at both 24 hours post-injury and 30 days post-injury to identify acute and chronic behavioral changes. The rodents were then sacrificed and brain slices were immunostained for caspase-3 and NeuN to identify apoptosis and neuronal loss. The results of this study provide data regarding the prevalence of caspase-3, as well as acute and chronic behavioral changes, following repetitive, low-level blast exposure. These results will aid in our understanding of the mechanisms underlying neurodegeneration after repetitive low-level blasts, allowing us to better protect military personnel consistently exposed to these blasts.

'CidaGel', an Antimicrobial Peptide Hydrogel

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Abstract: Over 6 million United States citizens are burdened by the complications of ineffective wound care, an issue that has continually plagued our healthcare system. Today's wound care market consists of many products with aims to promote healing and prevent infection yet show poor adhesion, rapid degradation, inefficient exudate absorption, lack of therapeutic release properties, and inability to prevent infection. Hence there is significant need for products that can promote tissue growth while maintaining a microbe-free environment in instances of acute (cuts, lacerations, burns and surgical/ accidental incisions and chronic wounds (diabetic foot ulcers, venous leg ulcers, ischemic ulcers, pressure ulcers) in the wound healing market. Our product, *CidaGel,* is a biodegradable peptide hydrogel that promotes angiogenesis and tissue growth while maintaining a microbe-free environment. Our preliminary data displays: (i) biometric nanofibrous architecture, (ii) acti-bacterial and anti-fungal response *(Streptococcus mutans, Lactobacillus casei, Pseudomonas aeruginosa,* etc.), (iii) cyto-compatibility and safety in rodents, (iv) injectability, and (v) biodegrading; features that would fill a void in today's wound healing market. *CidaGel's* commercialization will be further explored through the process of customer discovery. Overall, *CidaGel* has the potential to make a major impact in the wound care market, due to its distinct features which set it apart from other products.

Quantifying the Mechanical Competence of the Proximal Femur Using Finite Element Analysis

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Abstract:
Approximately up to 73% of bone has been found to be lost within the years following a spinal cord injury (SCI). People with osteoporotic bones are at much higher risk of fragility fractures and fracture-related complications. One treatment method that is rising in popularity is exoskeleton-assisted walking (EAW). With the use of exoskeletons rising for paraplegic patients, it is imperative to determine which patients can safely use EAW in order to prevent fractures in the lower half of the body. Therefore, it is necessary to find a way to measure bone density in a way that can be used clinically. Two of the main methods that are being used clinically to test eligibility for EAW are dual-energy x-ray absorptiometry (DXA) and peripheral quantitative computed tomography (pQCT). These methods are inaccurate in measuring the torsional stiffness and strength of bone. FE modeling and biomarkers add a layer of analysis and confidence to CT scans, allowing us to easily determine changes in the mechanical competency of bone. This project aims to develop evidence-based biomarkers that can determine the mechanical competence of bone in the proximal femur using finite element analysis. This fracture threshold will help clinicians safely prescribe exoskeleton-assisted walking to patients with complete spinal cord injuries. The mechanical competence of the proximal femur will be determined by first creating a finite element model from the CT scans. The proximal femur shall be manually segmented using imaging analysis software. The segmented bone models shall then be meshed in a FE-preprocessor. After the bone models are manually meshed, material properties will be assigned to elements and regions of interest using Bonemat and Python scripting. Finite Element tests will then be conducted on the bone model in Abaqus. Python scripts will then calculate the torsional stiffness and strength of the proximal femur. The expected outcome of this summer is determining bone stiffness and strength to determine an accurate fracture threshold through an analysis of the proximal femur using finite element (FE) modeling. This work will help validate finite element analysis as a viable alternative to the existing radiometric methods for determining bone strength.

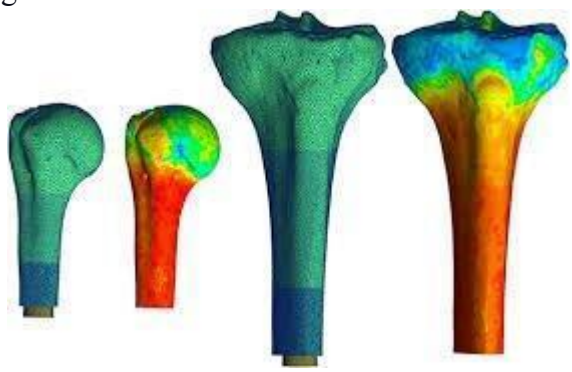

Figure 1: Finite Element Model of the Proximal Tibia

How does extinction affect and shape lineages in ant species over time?

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Extinction has shaped ecosystems throughout Earth's history, influencing species' evolution and distribution. The extinction of species through dispersion events creates vacuums in ecosystems, which can lead to significant changes in composition, food webs, and ecological functions. Removing a species can alter the dynamics of predation, competition, and nutrient availability, leading to surviving species adapting to altered environments. Integrating fossil records with observations of contemporary ecosystems provides valuable insights into the patterns and processes of extinction. The Dominican Republic, home to ancient amber deposits and diverse living ant species, offers a unique opportunity to study these dynamics. The genus Pseudomyrmex, currently present on the island, is also well represented in the amber fossil record with four species existing today and ten identified from fossils. By comparing the morphology of living and fossil species of Pseudomyrmex with data collecting methods and data analysis using programming tools such as R and Rstudio, this study aims to identify evolutionary change and the impacts of extinction on ant morphology and diversity. Namely, I will assess whether there was greater morphological diversity in the past than in the present. The results will explain how past extinction events have influenced current ant species' morphology and inform our understanding of biodiversity and extinction resilience.

Protein Corona Formation and Aggregation Studies on Targeted Drug Delivery Nanoparticles for Triple-Negative Breast Cancer

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Abstract: Protein corona formation and aggregation studies on targeted drug delivery nanoparticles present a promising approach to addressing the challenges presented by triple-negative breast cancer (TNBC). TNBC is an aggressive subtype of breast cancer characterized by the absence of estrogen, progesterone, and HER2 receptors, restricting the effectiveness of targeted therapies and traditional hormone therapies. Comprehending the creation of protein corona is essential as it has the potential to greatly change the biological makeup and behavior of nanoparticles, affecting their biodistribution and targeting effectiveness. In the same way, aggregation research is essential in order to prevent possible issues with nanoparticle functionality and stability in biological settings. Our project involves the synthesis of PLGA (poly (lactic-co-glycolic acid)) nanoparticles that are equipped with two key components: EGFR (epidermal growth factor receptors) targeting antibodies and PEG (polyethylene glycol) ligands. The EGFR-targeting antibodies are specifically designed to recognize and bind to EGFR that are overexpressed on the surface of TNBC cells, thereby improving the precise targeting of these cancer cells. On the other hand, PEG ligands are included to increase the nanoparticles' circulation time in the bloodstream and help them evade detection and clearance by the immune system. It's critical to distinguish between these two roles: although PEGylation, addition of PEG ligands, increases the duration of the nanoparticles' circulation, it does not guarantee that the particles will more efficiently target and aggregate in the intended tissues or cells. Therefore, to guarantee that the nanoparticles can successfully carry medications to TNBC cells, both the targeting capability offered by the EGFR antibodies and the extended circulation attained by PEG ligands must be adjusted separately. Using nanoparticle tracking analysis (NTA) and cross-polarization techniques, we aim to measure the size, viscosity, and aggregation behavior of these nanoparticles. This innovative approach seeks to optimize ligand combinations for improved nanoparticle stability and delivery efficacy. Developing a thorough understanding of how protein corona formation and aggregation affect our nanoparticle formulations will help us create more effective treatment plans for TNBC, which could result in important progress in the treatment of this challenging cancer subtype.

Optimizing the Quantification of Process-Related Impurities in Monoclonal Antibodies

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Therapeutic monoclonal antibodies (mAbs) are a rapidly growing class of drugs for autoimmune diseases and cancer. This progressive trend has established the need for rapid technologies to characterize mAbs to guarantee drug product quality and safety. One significant process-related impurity of mAbs is host cell proteins (HCPs). In therapeutic mAb manufacturing, HCPs pose risks to patient safety, which includes eliciting unpredictable immune responses. Thus, the identification of HCP impurities is essential to ensuring the efficacy of biopharmaceutical products. To characterize HCP contents in mAb samples and consequently improve biopharmaceutical products, protein samples are subject to enzymatic digestion, followed by analysis of resulting peptides using analytical chemistry technique, liquid chromatography-mass spectrometry (LC-MS). Protein digestion cleaves large proteins into small peptides that can be easily analyzed; concerning the mAb samples, protein digestion assists in dissociating the HCPs from the mAbs, thus preparing the sample for LC-MS analysis. However, protein digestion is traditionally a lengthy procedure, as it often requires thirty minutes to overnight incubation of proteins. Microdroplet digestion, however, is an ultrafast approach that has the potential to accelerate and complete enzymatic reactions in less than 1 millisecond. In this study, the mAb sample and an enzyme, specifically trypsin, are pumped simultaneously with separate syringes to digest the HCPs in the mAb samples. The mixture then enters an in-house microdroplet protein digestion apparatus. Different conditions are also altered and tested within the microdroplet protein digestion protocol to optimize the digestion process. This includes increasing the temperature of the system to 60 degrees Celsius using a heating cord. As a control, bulk digestion is conducted concurrently with the same source sample and enzyme. It is anticipated that applying microdroplet protein digestion in characterizing HCPs may expedite the analysis process. With the knowledge of the true amount of HCPs digested from a mAb sample, biopharmaceutical companies can not only prioritize managing HCPs but also improve upon their mAb therapeutics being manufactured for patient use.

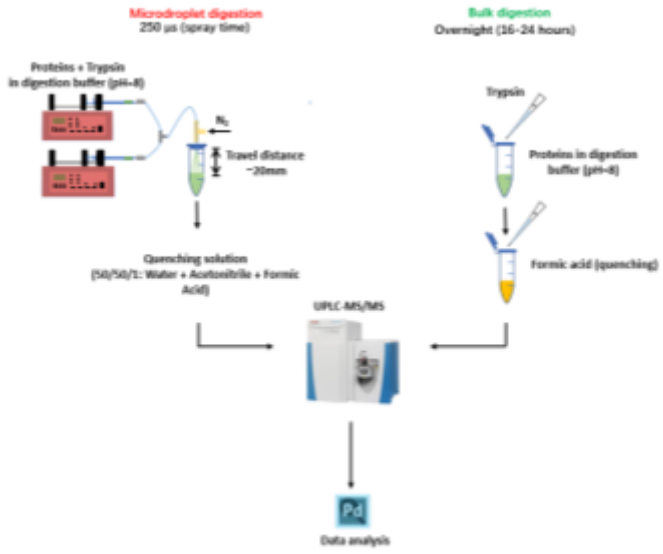

Figure #1. Comparison of microdroplet digestion protocol versus bulk digestion.

Developing an Objective Software Toolkit to Assess Pupil Asymmetry

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Convergence Insufficiency (CI) is a prevalent vision disorder affecting binocular coordination. This dysfunction is characterized by the imbalance in the rotation (vergence) of the eyes inward (convergence) and has commonly reported symptoms such as eye strain, headaches, blurred vision, diplopia, sleepiness, and difficulty concentrating. However the prevalence of CI varies, naturally-occurring CI occuring in between 3-10% of the general population while the rates of CI among individuals who have experienced a mild-traumatic brain injury (mTBI) and are diagnosed with persistent post-concussive symptoms convergence insufficiency (PPCS-CI) is up to 49% in children.

This project aims to develop analytical software to determine the differences in pupil response behavior analysis as an indicator of PPCS-CI. The key metrics to assess are the modulation of each eye's pupillary latency, initial relative change in pupil diameter (response amplitude), and the relative sustained pupil diameter (final diameter) from stimuli onset during repeated convergent eye movements. By examining these metrics, a difference in the temporal, positional, or symmetry of response can provide further understanding of commonly reported PPCS-CI symptoms and performance.

A total of 25 Binocularly Normal Controls (BNCs) aged 17.4 ± 3.4 years and 25 PPCS-CI patients aged 18.68 ± 1.7 years were analyzed. A ratio of each analyzed metric was taken from the minimum value of the left and right eye divided by the maximum observed value to determine asymmetry. Seen in **Figure 1A,** the BNC controls demonstrate an average ratio and standard error of 0.72 ± 0.2. The analyzed PPCS-CI asymmetry ratios demonstrate an approximately 20% difference compared to the BNC cohort with an average ratio of 0.567 and standard error of 0.33, which complements the average relative changes in pupil diameter between cohorts as seen in **Figure 1B.** Due to failure in Levene's assumption (1, 43, F=8.95, p=0.005) a Welch's t-test was used and demonstrated a trend (t(36.8) = 1.889, p = 0.067) between the average ratios. This preliminary analysis suggests that within the PPCS-CI cohort there is underperformance within one of the eyes compared to the relative symmetry of the BNC group. Future work will be focused on increasing the power of this analysis to determine whether this behavior can be utilized as a diagnostic performance metric.

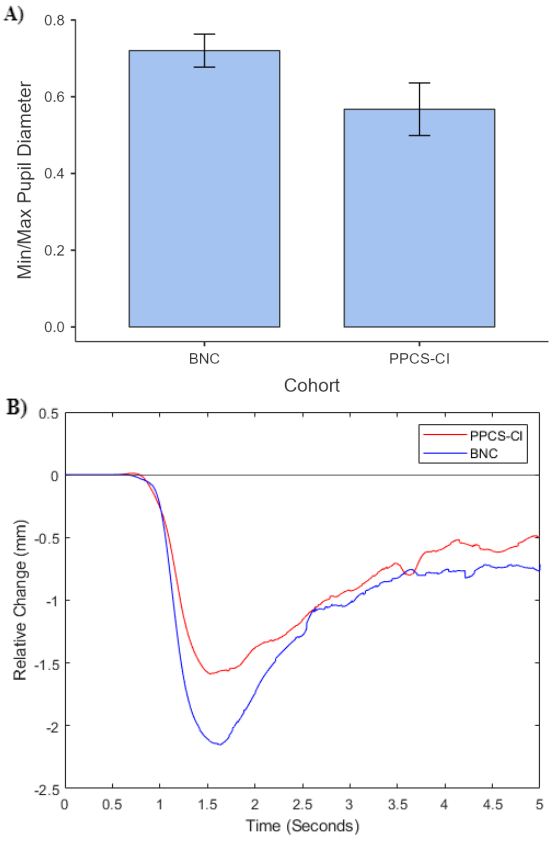

Figure 1. Describes average pupil response behaviors between BNCs and PPCS-CI patients. **Figure 1A.** shows the average pupillary response ratios of the minimum/maximum pupil diameter for each subject within each cohort with one standard error above and below each mean. **Figure 1B.** illustrates the behavioral average relative change in pupil diameter for each cohort.

Upstream Migration of Natural Killer Cells

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Abstract: The hallmark of an immune response is the recruitment of leukocytes to an inflammatory site. Natural killer (NK) cells are amongst the innate immune leukocytes that target tumor cells and cells infected with viruses.NK cells circulate the bloodstream to identify cells that have been infected with infectious cells. All cells have a specific form of major histocompatibility complex (MHC class I) protein expressed on the cell membrane. As an NK cell travels through the bloodstream, its inhibitory receptor will try to bind with MHC class I proteins. Should binding occur, the "killing" mechanism of the NK cell will be inhibited, indicating that the cell is native to the body. If the NK cell is unable to bind with the MHC class I gene of another cell, the NK cell will destroy it, assuming it is a pathogen invading the body. Additionally, cells that release activating signals, such as cancer cells, may also prompt NK cell destructive responses.

This project will characterize the behavior of NK cells as members of the leukocyte adhesion cascade. The aim of this project is to determine the migration of natural killer cells in the endothelium in an *in vitro* device that models the endothelial layer and shear flow of the blood. The leukocyte adhesion cascade is a stepwise process that allows leukocytes to migrate out of the bloodstream to surrounding tissues where infection or inflammation is present. In this series of steps, leukocyte will begin rolling along the inner layer of the endothelium as a result of weak selectin binding and will be halted as a result of strong integrin binding. After doing so, they will transmigrate through the endothelium to the site of inflammation or infection. The goal of this study will be to see if NK cells are able to perform the leukocyte adhesion cascade upstream or downstream against the shear flow. Movement in response to shear flow will be correlated with the integrins that are seen on the natural killer's surface to potentially understand if certain integrins cause upstream or downstream migration in the bloodstream. In order to do so, the natural killer cells will be cultured using IL-2 containing medium allowing the cells to grow to be used for further research. After cell growth, some cells will be used in flow cytometry. Staining with antibodies will be done and then flow cytometry will be run. This will be done to display the integrins that are present on the cells' surfaces. Additionally, the NK cells will be inserted into a microfluidic device that simulates the environment of the blood stream, specifically, the shear flow. The cells will then be observed if they move upstream or downstream against the shear flow that is established in the device, ultimately simulating the blood *in vitro*. Based on literature reviews, NK cells express Mac-1 heavily, an integrin that is seen with downstream migration of macrophages. Hence, it can be anticipated that primarily downstream migration will be seen in natural killer cells. By characterizing NK cell behavior, we can lay the foundation to future work involving altering the NK cell integrins using guide mRNA to inhibit the expression of certain integrins with the hope that this alters their behaviors in the microfluidic device.

Designing Waste Disposal System of Small-Scale Peptide Synthesizer

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Abstract: Automated peptide synthesizers are widely used in the industry of pharmaceutics. Peptide synthesizers revamped medicinal chemistry by increasing productivity in the development of peptide drugs, reducing errors in peptide synthesis, and increasing research throughput. Most synthesizers perform solid-phase peptide synthesis (SPPS). Although large-scale peptide synthesizers can synthesize lengthy chains of amino acids, there are still disadvantages. These synthesizers are expensive, not portable, and produce massive amounts of hazardous waste. The waste components consist of dimethylformamide (DMF), piperidine, oxyma, acetic anhydride, etc. This project aims to fabricate a small-scale automated peptide synthesizer. Thus, this synthesizer will be affordable and portable. My objective is to create an efficient waste disposal system for the miniature synthesizer. Computer-aided design software such as AutoCAD and Fusion360 are being utilized to make this waste disposal system. The proposed design for the waste disposal system is an elastic nylon balloon. Since the waste balloon will be in the inner workings of the synthesizer, a mechanism has been established to ensure the removal of the balloon in the safest manner. The proposed mechanism is a drawer for the waste disposal balloon. This will be advantageous when considering the removal of the waste balloon from the synthesizer. The expected results will include the balloon attached to an O-ring, embedded in the drawer, which will be directly connected to the waste valve in the synthesizer. The design of the waste disposal system will be a crucial part of the novel point-of-use miniature peptide reactor.

Nanoplastic Exposure May Contribute to Abnormal Placenta Development in Mice

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Abstract**:** The amount of plastic waste has dramatically increased in the past hundred years and is now present in every area of the planet. Microplastics (MP) and nanoplastics (NP) derived from plastic waste degradation are capable of entering the human body, potentially leading to significant negative health effects. MPs have been detected in the human placenta, but their effects are not fully understood. Placenta Accreta Spectrum (PAS) disorder is characterized by abnormal placental growth into surrounding tissue, which can lead to life-threatening blood loss during childbirth. Several biological processes are implicated in PAS disorder, including abnormal cell growth, adhesion, and migration. The effects of MP and NP exposure on the developing placenta are unknown. We hypothesize NP exposure during pregnancy will affect biological processes in the placenta which may contribute to PAS disorder. To test this, pregnant adult CD-1 mice were exposed to either water, 5 mg/kg of 50 nm polystyrene NP, or 5 mg/kg of 200 nm polystyrene NP beginning on the 8th day of pregnancy for one week. Afterwards, the mice were euthanized, and placenta samples collected for gene expression analysis using real time quantitative reverse transcription polymerase chain reaction (qRT-PCR). We found that expression of genes relevant to cell growth, adhesion and migration processes were considerably altered after exposure to polystyrene NP, suggesting that exposure to NPs may lead to abnormal placental implantation and growth. In addition, the sex of the fetus may mediate the extent of changes in gene expression in the placenta after NP exposure. Our results indicate that plastic exposure may affect crucial processes for the development of PAS disorder.

Developing Monomers for Sequence Defined Oligomers in Nucleic Acid Therapy

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Nucleic acid therapy is a rapidly developing treatment to fight different types of diseases. Nucleic acid therapy differs from small molecule drugs and antibodies as it stimulates the cell to produce (or suppress the production) of proteins as a pharmaceutical modality. Nucleic acid therapy relies on a vector to deliver mRNA and siRNA into a cell, such as lipid nanoparticles (LNPs) or CARTS (Charge-Altering-Releasable-Transporters). The research conducted this summer looks specifically at sequence defined oligomers as vectors for nucleic acid delivery. These oligomers are synthesized from monomers and can vary in size and composition. The types of monomers that are put into the oligomer determine the oligomers' function and viability. Sequence defined oligomers are generally smaller than polymeric gene delivery vectors and are less likely to trigger an immune response. The goal in building sequence defined oligomers is to create the most efficient and effective molecule for cellular transfection, ultimately providing a tool to develop gene therapy treatments of various diseases. The overarching goal of this summer research is to synthesize a variety of monomers all with slightly differing properties and test their functionality in cell lines when acting in sequence defined oligomers. Previous work has demonstrated the efficacy of using amino acids as the building block in monomer synthesis. The research will repeat the synthesis of a glycine based cyclic monomer. New synthetic methods will be developed to synthesis a linear glycine-based monomer. Additionally, this research will explore varieties of amino acids including but not limited to: lysine, phenylalanine, and aspartic acid. All these amino acid bases have different properties and will hopefully affect the efficacy of the sequenced defined oligomer in different ways. When testing these sequenced defined oligomers in cell lines this research will be able to highlight how monomer properties effect transfection efficiency. Future research would develop further monomers and sequence defined oligomers building on the understanding gained in these studies.

Parafilm for Fabrication of Inexpensive Microfluidic Platforms

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Microfluidic devices are often used instead of animal models for disease modeling due to their low cost and potential for human cell integration. Previous work has been done to fabricate microfluidic devices using Polydimethylsiloxane (PDMS), but this is an often time consuming, laborious, and expensive process. There is thus a need to create inexpensive microfluidic platforms for disease screening, progression, and modeling. Here, we report a double layer parafilm microfluidic platform with a total fabrication time of 20 minutes. A laser cutter is used to create microchannels while leaving a bottom parafilm layer intact. This glass + parafilm + glass microfluidic setup is heated at 60 °C for 20 minutes on a hotplate, and a styrofoam box is placed on top of the microfluidic device to add 20kPa of uniform static pressure to enhance parafilm adhesion and prevent leakage. Inlet and outlet holes are drilled into the top glass slide using diamond drill bits, and tube connectors are superglued to both openings to allow for flow. Future work must be done to seed inlets with human mesenchymal stem cells to study their differentiation into endothelial cells under shear stress and their adherence to the inner lining of the parafilm channel.

Fluid Dynamics of Schooling and Migrating Elasmobranchs

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Shark schooling behavior – wherein sharks swim collectively in coordination – may play a pivotal role in their hydrodynamics and overall locomotion efficiency. Despite the potential hypothesized benefits of schooling behavior, such as enhanced survival strategies, improved foraging, and energy conservation, the hydrodynamics of this behavior remain largely unexplored and warrant further research. Understanding the fluid mechanics involved in the collective behaviors of schooling sharks is crucial for gaining insights into their energy efficiency and locomotor strategies, for providing models for efficient collective movement in engineering and robotics. This research aims to examine a biologically relevant model of schools of swimming Blacktip sharks (*Carcharhinus limbatus*) and simulate the underlying flow dynamics around individual sharks and within small groups. Drone footage was used to track and monitor shark schools in their natural habitat, while computational fluid dynamics were employed to analyze flow patterns and quantify drag reduction, velocity and pressure gradients under different schooling formations. The findings provide insights into the hydrodynamic interactions within shark schools and their efficiency in drag reduction at varying speeds and positions within the school. Future work will focus on expanding these findings to other species and exploring the potential for bio-inspired design in underwater technology by emulating collective behavior mimicking efficient swimming strategies.

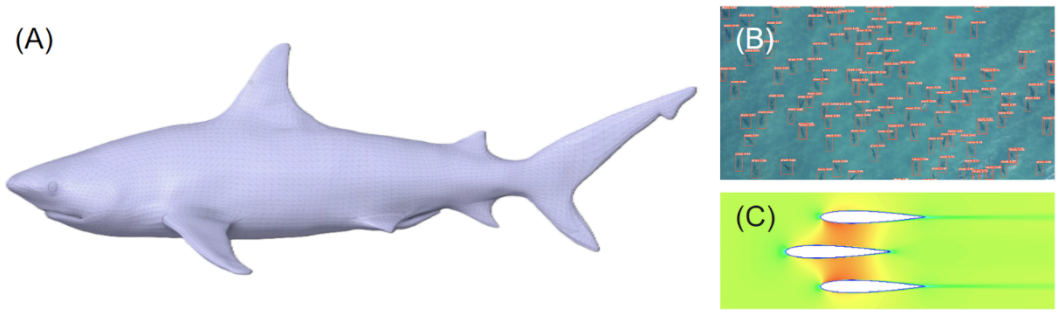

Figure 1: (A) Blacktip shark model (Carcharhinus limbatus). (B) Drone footage with custom detection of individual sharks. (C) 2D CFD Velocity field contour preliminary results.

Using Light To Stimulate Dmrt3a Neurons, A Genetic Class of Spinal Interneuron, In Zebrafish Larvae To Determine Its Functional Role In Motor Behavior

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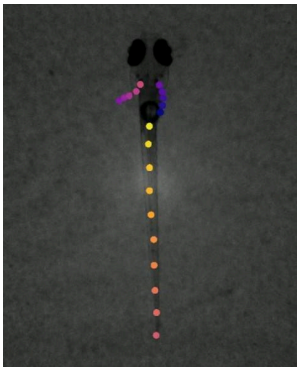

Figure 1. Image of larval zebrafish (rostral at top) with overlap of successful tracking by DeepLabCut where the two pectoral fins (left is abducted right is adducted) and the tail are visible. The fish is approximately 4 mm long. Image from Severi Lab.

Neurons, the fundamental unit of the brain and spinal cord work together in neural circuits to control motor functions from a simple step to swimming. Studying these neural circuits allows for a broader understanding of neurons involved in motor disorders and could advance targeted drug development. This study focuses on the connection of spinal interneurons, a group of neurons in the spinal cord, to the *Dmrt3a* gene and its role in coordinating movement. Interneurons that express the *Dmrt3a* gene in fish and the homologous DMRT3 gene in mammals were found to influence locomotor coordination and speed regulation in organisms such as horses and mice in previous studies. In our study, we hypothesize that neurons that express the *Dmrt3a* gene are vital for coordinating effective locomotion in larval zebrafish. We will test this hypothesis by optogenetically activating these neurons with light, observing the movement of the pectoral fins, and comparing the effects of larval zebrafish with and without activating the interneurons. By observing how the zebrafish move their pectoral fins and tails when this neuron is activated, we hope to learn more about how these neurons control movement. This knowledge could help us understand and treat human nervous system movement disorders like Parkinson's and improve recovery from spinal cord injury.

Unveiling the Functional Connectivity using fMRI

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Abstract: Neuropsychiatric disorders, such as Schizophrenia, Epilepsy and Attention Deficit Hyperactivity Disorder, are increasingly prevalent, affecting over 1 billion people worldwide (WHO, 2020). In the United States alone, mental health conditions account for approximately 18.3% of the total burden of disease (NIMH, 2020). The need for early diagnosis and effective treatment has never been more pressing.

Functional magnetic resonance imaging (fMRI) offers a non-invasive technique to measure neuronal activity in the brain with excellent spatial and temporal resolution. By detecting changes in blood oxygenation, fMRI provides valuable insights into brain function through the Blood Oxygenation Level-Dependent (BOLD) signal. The BOLD signal serves as a proxy for neural activity, enabling the estimates of brain function and connectivity. Functional connectivity analysis using fMRI has become pivotal in understanding brain organization and dynamics. This study employs Region of Interest (ROI) calculation methods to investigate functional connectivity patterns among brain regions.

Resting-state fMRI (rs-fMRI) is a type of fMRI imaging that measures brain activity when a person is not performing any specific task or function. The significance of rs-fMRI lies in its ability to- 1) Identify brain regions that are functionally connected and form networks, even when the brain is at rest, 2) provide insights into brain function, especially in regions involved in attention, memory, and default mode processing. The rs-fMRI doesn't require subjects to perform tasks, making it ideal for studying populations with cognitive or motor impairments.

Functional connectivity (FC) in the brain refers to the synchronized activity between distinct brain regions, forming complex networks that underlie cognition, behaviour, and brain function. FC has emerged as a vital biomarker for early diagnosis and spatial localization of the dysfunction in the brain for neuropsychiatric disorders.

In this study, we employed fMRI to estimate FC in healthy controls (HC) and individuals with neuropsychiatric disorders. We analysed FC patterns in both groups, revealing significant differences in network organization and connectivity strength. Resting-state fMRI data from a cohort of healthy subjects were pre-processed to mitigate noise and artifacts. ROIs were defined based on anatomical landmarks or functional networks of interest. Primarily, time-series data were extracted from ROIs and correlation matrices computed to quantify interregional connectivity & then from those data the visualization of these connectivity patterns, elucidating networks implicated in various cognitive processes was facilitated.

Our findings demonstrate the potential of FC estimation using fMRI and advanced analytical techniques as a biomarker for early diagnosis and localization of brain dysfunction in neuropsychiatric disorders. This work contributes to the development of novel diagnostic tools and therapeutic strategies, ultimately improving the lives of millions worldwide.

Effect of EMF Exposure to T47D Cells

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Invasive treatments for cancer such as chemotherapy, drugs, and surgery have been shown to have severe side effects such as toxicity to healthy cells, and long recovery times. Furthermore, their effectiveness is limited in preventing metastases and are further restricted by their high cost [1]. Because of this, a non-invasive and more effective treatment for cancer is highly desirable to discover. In previous work it has been shown that electro-magnetic fields have a negative effect on a variety of cancer cells (including T47D breast cancer cells), while having a minimal effect on healthy cells (such as MCF-10A healthy breast cells) [1]. This paper will demonstrate the effect a static magnetic field has on T47D cells by showing a transient effect on cell life through time, and comparing that to the effect on MCF-10A cells. This was done by generating a magnetic field through a helmholtz coil of varying intensities, placing the cells within the range of the coil, and imaging the cells throughout a 4 hour time frame. We have successfully conducted this experiment, and have observed a noticeable decline in cell life for the T47D cells earlier than the MCF-10A cells. This is especially noticeable at a higher magnetic field intensity. Future research can be conducted to refine the field strength, and measure the metabolic rate of the cells while in the field.

References

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Targeted Delivery of Platinum Nanoparticles for Triple-Negative Breast Cancer Treatment

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Abstract: Triple-negative breast cancer (TNBC) is an aggressive form of breast cancer characterized by the absence of estrogen, progesterone, and HER2 receptors. This lack of receptors renders conventional hormonal therapies and HER2-targeted treatments ineffective, resulting in a poorer prognosis and limited therapeutic options. Current treatments, such as chemotherapy, often inflict severe side effects and resistance due to their non-specificity in targeting cells, causing toxic effects on patients. This underscores the urgent need for novel treatment strategies. This study aims to explore the potential of platinum nanoparticles (Pt NPs) as a targeted delivery system for TNBC treatment. Pt NPs could offer more precise therapy with reduced side effects and increased efficiency compared to traditional treatments. The Pt NPs will be modified with PEG and PLGA to enhance circulation time and safety. They will also be functionalized with targeting ligands specific to TNBC cells, such as the epidermal growth factor receptor (EGFR), to target TNBC cells accurately. In vitro studies will evaluate the uptake efficiency, cytotoxicity, and efficacy of the Pt NPs to demonstrate their specificity and efficacy in targeting TNBC cells. The targeted delivery is expected to reduce off-target effects, thereby minimizing chemotherapy side effects and addressing drug resistance, potentially leading to improved patient outcomes. Future in vivo studies will assess biodistribution and long-term therapeutic effects, potentially advancing TNBC treatment and improving patient outcomes.

Real-time Monitoring of Extracellular Matrix Remodeling During Breast Cancer Progression

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Abstract: The metastatic cascade begins with migration of the tumor cells from the primary site and intravasation into blood or lymph vessels. This involves complex biological processes, including the epithelial-mesenchymal transition for migration and matrix degradation for intravasation. Current methods for screening tumor malignancy involve biopsies, which are invasive, expensive, and detrimental to a patient's health. The local microenvironment of a cell, the extracellular matrix (ECM), has specific biomechanical properties that are key steps in the metastatic cascade of the tumor and its response to therapy. The design of a three-dimensional hydrogel-based ECM would monitor physical changes during breast cancer cell migration and progression, determining tumor malignancy noninvasively. This research will utilize hydrogels with varying ECM composition to study how ECM stiffness, topology, and protein deposition changes during ECM remodeling of the MDA-MB-231 aggressive breast cancer tumor model. With 3D organoid models there will be an increased surface area to reduce the noise for personalized medicine approaches. Electrochemical analysis and mechanical testing will be utilized for real-time monitoring of the cell-associated changes in matrix stiffness, degradability, and porosity. Through monitoring of the ECM remodeling, the aim is to develop noninvasive real-time monitoring techniques for cancer progression diagnosis.

Responses to Emotional Video Stimuli in TBI Patients: an fNIRS Study

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Traumatic Brain Injury (TBI) is a term used to categorize a set of injuries that result from physical trauma to the head. These injuries are prevalent in all ages through a variety of causes, such as sports injuries, motor vehicle accidents, and falls. In these TBI cases, there are often symptoms, including reduced cognition, altered behavior, and physical disabilities, which can significantly affect patients' recovery prognoses and quality of life. In order to study the physiological changes associated with these symptoms of TBI, neuroimaging modalities such as functional magnetic resonance imaging (fMRI) or electroencephalography (EEG) are used.

One such imaging modality that has seen increased use in TBI-related research is functional near-infrared spectroscopy (fNIRS). fNIRS is a neuroimaging modality based on the use of optical light to image and analyze the movement of hemoglobin throughout the brain. This is done using optodes that emit a laser with a wavelength between 650 and 1000 nm, which is then read by a detector that measures the optical density of the returning light. This absorbance can then be used to determine the hemodynamics in regions of the brain over time. These hemodynamics are additionally correlated with neuron activation, allowing for a cost-effective, portable, and non-invasive method of measuring neuronal activity.

This study will apply the fNIRS technology to compare TBI patients and healthy controls to determine if there is an underlying physiological difference between the emotional responses of the two groups. This will be done using 50 participants aged 18 to 35, with 25 participants having a history of mild-moderate TBI and 25 healthy controls. fNIRS data will be measured from each participant using a specifically designed optode cap that will collect data primarily from the brain's frontal lobe. Each participant will be asked to perform three tasks during one data collection session. First, they will complete a resting-state fNIRS scan where data is recorded while they are told to pay attention to a blank screen. Secondly, they will watch a 15-minute short film and then rate their emotional responses using a Self-Assessment Manikan (SAM). Lastly, they will watch ten short-form 30-second videos associated with either positive or negative emotions and complete a SAM after each video. The resting state and dynamic functional connectivity will be calculated for each of the different trials and videos, and between-subject comparisons will be examined between the TBI and Healthy groups.

At the end of this project, we expect to see a difference between the TBI group and the healthy controls in their emotional responses to the different video formats through both their SAM scores and within the TBI data. In the future, the results of this study can be applied clinically to TBI diagnosis procedures and treatments in order to ultimately help improve the recovery and lives of patients. Additionally, future research using the same technique and study design can be performed in order to see the physiological changes associated with other neurological conditions.

Sequence-Defined Polyester Oligomers for Nucleic Acid Therapy

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Abstract: Nucleic acid therapy is a new and rapidly developing therapeutic modality with applications for the treatment of genetic and acquired diseases. A critical limitation to the use of nucleic acid therapy is the delivery system chosen to protect and transport functionally intact nucleic acids to target cells and tissues. Sequence-defined polyester oligomers demonstrate potential to overcome the barriers faced by current viral and lipid nanoparticle delivery systems. Sequence-defined polyester oligomers, through their unique charge-altering degradation mechanism, offer biotechnologists the opportunity to reduce frequency and size of nucleic acid doses while reducing off-target toxicity and harmful immune responses in patients. Furthermore, the easily scalable production of polyester oligomers enables their application as affordable off-the-shelf delivery tools, expanding access to nucleic acid therapy across socioeconomic and geographic differences. This project explores the effects of oligomer sequence properties and monomer identity on the degree of delivery of functional nucleic acids (transfection efficacy) to various cell types. Sequence-defined polyester oligomers are synthesized with variations in position of cationic and lipidic monomers, through a novel application of flow chemistry to charge-altering releasable transporter (CART) monomers. Transfection efficacy of the sequence-defined polyester oligomers is tested in vitro using a messenger RNA cargo (FLuc mRNA) that, when delivered and released intact into cells, induces fluorescence. Stability of the produced FLuc mRNA-oligomer nanoparticles will be measured with dynamic light scattering techniques. Cell lines will then be treated with different sequence-defined oligomer nanoparticles. The strength of fluorescence across the different oligomers will be compared to identify any relationships between monomer sequence and transfection efficacy. The outcome of this project is new understanding of sequence properties and monomer identities that enable successful transfection for the assayed cell types. Findings regarding transfection efficacy will guide design of sequence properties and monomers to be tested in future full-body assays for organ and tissue specificity.

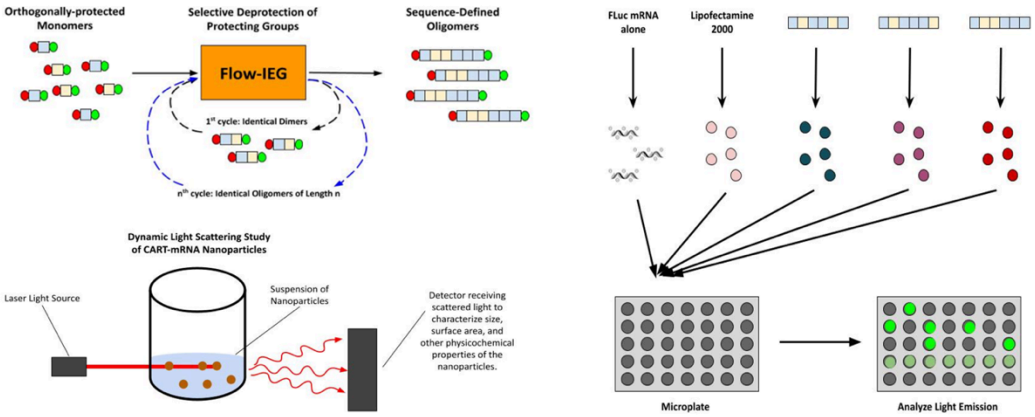

Figure 1: Experimental design to test effects of sequence properties on transfection efficacy of polyester oligomers.

Quantifying Gait Abnormalities in Children with Cerebral Palsy through 3-D Motion Analysis Techniques

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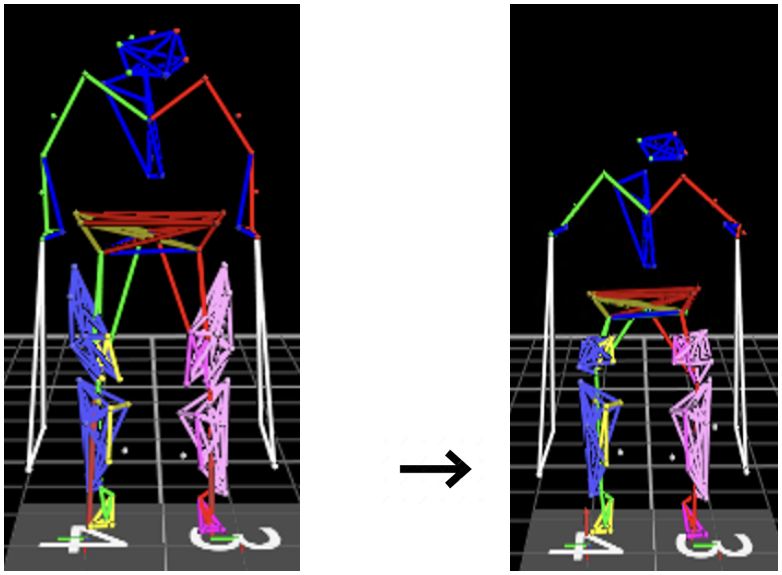
Abstract: In the current scope, the utilization of exoskeletons is the only non-invasive method through which individuals with spinal cord injury (SCI) are able to regain their mobility. Although the initial plan for this research involved children with cerebral palsy, the patient population was switched to adults with spinal cord injury. Although the populations are different, the research methods are the same between them. While using exoskeletons, patients may often experience large forces or torques on their lower extremities at key points such as where the exoskeleton attaches. These forces and torques can often result in fractures that slow down rehabilitation and make it increasingly difficult for mobility to be regained. The objective of this study is to measure the interactions between human and exoskeleton from seated to standing and standing to seated positions. To understand these interactions, we utilized 3 FDA approved exoskeletons in which participants were placed: Indego, Ekso, and Rewalk. An individual with SCI was recruited and participated in 3D motion capture trials at the Life Science Motion Capture Lab at NJIT. Marker trajectories were collected through the use of infrared cameras and reflective markers placed at key locations on subjects' bodies as well as the exoskeletons. In addition, ground reaction forces were simultaneously collected by force plates which the participants were instructed to walk over. Once collected, data was then organized and processed utilizing Vicon Nexus which allowed us to have complete models showcasing exoskeleton assisted motion.



Use of Self-Assembling Peptide Hydrogel for Dental Pulp Regeneration

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Abstract: Root canals are a highly common procedure performed by dentists, where inflamed or infected dental pulp is removed and replaced by an inert material (such as gutta percha). This procedure effectively kills the tooth, reducing its overall mechanical strength and leaves it suspectable to breakage and reinfection. There is a large unmet market need for a new dental filler that is biodegradable, can kill primary tooth infection, prevent secondary infection, and stimulates the regeneration of the natural dental pulp. Our biomaterial, 'Cidagel', is designed to be an off-the-shelf product that is easy and low cost to manufacture, requires a simple clinical procedure, and can be infused with a radiopaque reagent. 'Cidagel' is composed of self-assembling peptides, which form into a hydrogel upon injection. This peptide hydrogel exhibits extracellular matrix (ECM) mimicry and is both angiogenic and antimicrobial, essential characteristics needed to support the regeneration and survival of dental pulp. To test this biomaterial in vivo, we have performed both pulpectomy and apical periodontitis studies in rodent models and are beginning the same studies in swine models. After application of our biomaterial, the tissues of interest are collected at specific timepoints (7, 14, 21, and 28 days after injection), CT scanned, and histologically analyzed for their effect on the dental pulp. Pulp regeneration is quantified through the measurement of blood vessels and living tissue formation within the missing or infected tooth model. The commercialization potential of this product will be explored through customer discovery interviews.

Computer-Aided Ligand Design for the Sigma-2 Receptor to Increase Anti-Neuropathic Pain Activity

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Mentor: Joseph Dodd-o [2]
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Abstract: Neuropathic pain has a massive impact on a patient's quality of life, typically occurring in the aftermath of diabetes, chemotherapy, aging, or obesity. Despite currently affecting between 7-10% of the U.S. population, established treatments directed towards neuropathic pain are limited. The treatments currently in use for neuropathic pain are tricyclic antidepressants or non-steroidal anti-inflammatory drugs (NSAIDs). These medications are not made to address the biological mechanisms of neuropathic pain, instead focusing on mitigating its symptoms. Therefore, it is crucial that a safe and effective therapy to address neuropathic chronic pain is developed. The sigma-2 receptor (S2R) is abundant among the peripheral nervous system (PNS) and has a proven capacity to produce anti-allodynic effects. This study will utilize computational methods to treat S2R as a target for peptide-based therapies with the intention of alleviating neuropathic pain. Using the Rosetta suite of macromolecular modeling functions parsed with RosettaScripts, five thousand randomized amino acid sequences were generated alongside their binding energy scores. The top ten sequences with the lowest binding energies were tested further using conformer RMSD analysis. The ligands will be then synthesized via solid-phase peptide synthesis and tested to verify that their identity, characterization, and binding matches the computational models. Subsequent in vivo studies will assess the anti-neuropathic pain effects of the ligands generated.

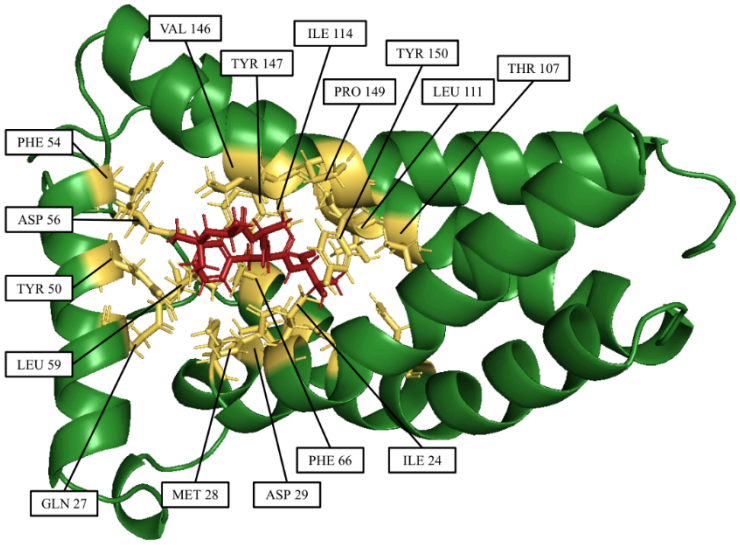

Figure 1: 3-D Model of the generated ligand, in red, bound to the S2R, in green. The interacting amino acid residues between the ligand and S2R are represented in yellow. Screen capture taken from PyMol.

Piezoelectric Fingers for Tumor Detection

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Abstract: Breast cancer is the most common cancer in America, making up 30% of all newly diagnosed cases each year. Breast tumor size and spread are used to diagnose cancer mainly through mammograms. Although women over the age of 40 can regularly get mammograms, younger women often face high costs due to lack of insurance coverage when attempting to get screened. A cheap, portable screening method for breast tumors that can be performed independently will increase early cancer detection and lower mortality rates. Piezoelectric polymers, which generate charge in response to mechanical stress, have much potential for sensing applications due to their excellent flexibility and ability to be self-powered. Electrospinning the polymer results in highly piezoelectric, flexible nanofibers that can be fabricated into a battery-free sensor for biomedical applications. Through harnessing the piezoelectric effect, a nanofibrous sensor can be developed to measure the elastic modulus of tissue since breast tumors and healthy breast tissue have reported elastic moduli of approximately 10 kPa and 800 Pa respectively. Conventional tests with materials of different stiffness and constant applied force were performed to correlate the device's output voltage with material stiffness. Future work will optimize device design and incorporate circuitry to eliminate operator dependance.

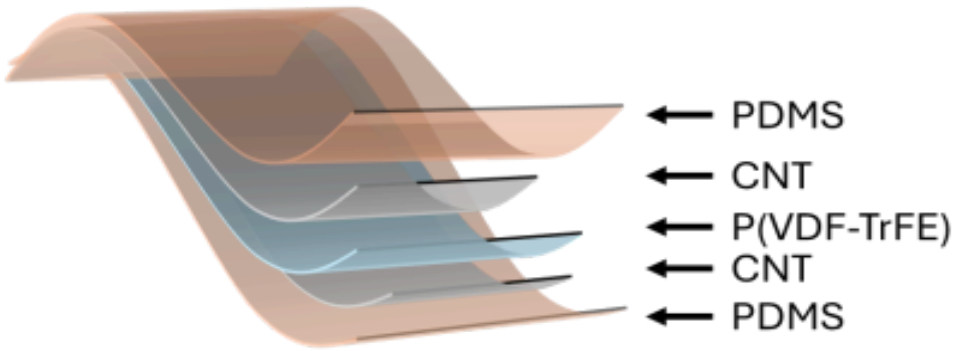

Figure 1. Layered schematic of the flexible piezoelectric nanofiber-based device. Poly(vinylidene fluoride-trifluoroethylene) (P(VDF-TrFE)) nanofiber film is encased with a carbon nanotube (CNT) mask for electrical conductivity and polydimethylsiloxane (PDMS) for biocompatibility and mechanical strength.

An Analysis and Optimization of the Factors That Impact Anaerobic Digestion and Biodigester Efficiency

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Abstract: 40% of food in the US becomes food waste, displaying a clear issue in both food distribution and waste management within the food industry. The decomposition of this organic waste emits methane gas, a greenhouse gas 25 times more potent than carbon dioxide, into the atmosphere. Biodigesters provide an alternative management solution to landfills, reducing atmospheric greenhouse gasses and providing alternative energy. Biodigesters are a technology that facilitate the production and collection of biogas (primarily composed of methane) through the process of anaerobic digestion. Anaerobic digestion is a multistep process that first breaks down food into basic monomers through hydrolysis, and creates biogas and digestate (a material that can be repurposed as natural fertilizer) in its final step of methanogenesis. The efficiency of this process is greatly dependent on environmental conditions and the presence of necessary microorganisms. Understanding and determining ideal conditions for anaerobic digestion is imperative for optimization of biodigester technology, which would in turn encourage widespread implementation of the sustainable waste management and alternative energy source.

This research aims to specifically understand the optimal microorganisms to introduce to the biodigester. Microorganisms for anaerobic digestion are present in seed materials, including animal feces, compost, and anaerobic sludge from wastewater treatment facilities. These seed materials house different microbial communities, and therefore have varying levels of efficiency when introduced to food waste in a biodigester system. In a 4 beaker system facilitating anaerobic digestion at a small scale, the ideal seed material (or mixture of seed materials) can be quantifiably determined through the measurement of methane gas. The anaerobic digestion takes place in the first beaker, and a tube transports the resulting biogas into the second beaker where the CO_2 is scrubbed, and the remaining methane gas travels to the 3rd beaker, displacing the water from the 3rd beaker to the (initially empty) 4th beaker. The amount of water displaced is equal to the quantity of methane produced by the digestion taking place in the 1st beaker.

The goal is ultimately to determine the ideal seed material (or ratio of seed materials) for biogas production. The findings of this research can lead to improvements in biodigester technology, and will be utilized during the design and implementation of an on-campus biodigester.

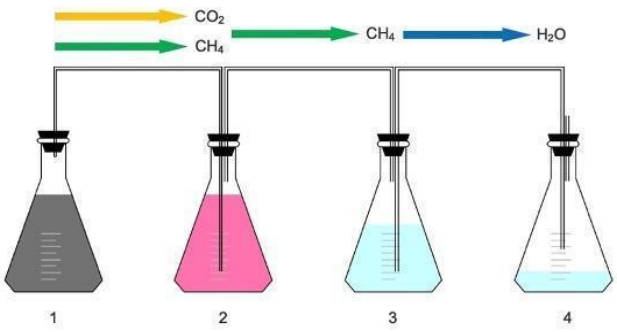

Figure 1: Procedure setup, composed of a food + seed material mixture in beaker 1, a calcium hydroxide CO_2 scrubber in beaker 2, water in beaker 3, and an empty 4th beaker to collect displaced water.

Quantifying The Whole-Body Center Of Mass From 3D Motion Data

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The Center of Mass is an essential concept in biomechanics and is important for understanding human motion, stability, and balance. It gives us the average body mass location and substantially influences stability during daily activities like walking, running, and moving around. Measuring the center of mass displacement during gait is a critical aspect of understanding biomechanical characteristics and gait efficiency. My goal for the summer was to develop a MATLAB script to accurately quantify the whole body center of mass (COM) of human subjects using 3-D marker trajectories collected at the Life Sciences Motion Capture Lab. This research project addresses the differences in COM between various subjects during walking trials. My main goal is to create data processing algorithms to calculate and validate the accuracy of COM calculations for able-bodied subjects.

Initially, I created a code that calculated the center of mass for each segment in the body, including the pelvis, femur, tibia, foot, humerus, radius, hand, thorax, and head. I formulated a code that uses the marker placements of each part of the body to calculate the COM. I went segment by segment to match the COM with the COM from the Vicon data. I computed each center of mass successfully aligning with the COM calculations from the Vicon software. Using the individual centers of mass, I was able to quantify the whole body center of mass by adding them all up. This was done for a static trial where the subject was just standing. Next, I worked on the walking trials for able-bodied subjects. I implemented my static trial code for the walking trials to calculate the center of mass when a human is walking. I had to modify the code to fit the walking trials as now the person was in motion.

For the walking trials, there was a complication with the human gait as the person will never accurately walk in a straight line, creating different walking patterns leading to the medial Lateral and Anterior Posterior center of mass to change. This creates discrepancies in the final plot for the center of mass. My future goal will be to normalize the distance so we can get more accurate results for the walking trial of the able-bodied subject. Another future goal is to be able to calculate posterior stability for able-bodied subjects. If the code is successful it can be applied to exoskeleton-assisted walking trials which can help with the lab's research.

Methacrylated Alginate/Gelatin Blends as Bioinks for Tissue Engineering Applications

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Three-dimensional (3D) bioprinting has opened countless new possibilities for medical research and applications. Bioinks could be used to create 3D habitats for cells to simulate life in a real human body. The demand for tissue substitutes that closely resemble native tissue and enhance cellular behavior is growing, but a major challenge in bioink fabrication is creating a bioink that can be printed into a structure with a similar stiffness to the stiffness of the target tissue. Methacrylated alginate (MeAlg) is commonly used as a bioink as it does not have inherent bioactivity to support cell function but enables tethering of bioactive cues to instruct stem cell behavior such as differentiation into specific tissues. However, printable formulations contain high concentrations of alginate polymer (10-20 wt./v %) leading to dense constructs with much higher stiffness as compared to soft tissues such as cartilage. In this study, gelatin is used as a sacrificial thickening agent to enhance printability of bioink formulations with low MeAlg concentration (≤10%) and removed after bioprinting by simply dissolving it. MeAlg/gelatin blends, ranging from 10% to 0% MeAlg to gelatin ratio, are formulated to investigate ink rheology, printability and mechanical behavior of the printed constructs. The findings from this research could have significant effects on future work in 3D bioprinting technology by fabricating bioink to resemble soft tissue and have potential applications in tissue engineering, including cartilage treatment.

A Modeling Framework for Simulating Skin Decontamination of Chemical Warfare Agents

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Abstract: According to the World Health Organization, 2 million people died due to exposure to toxic chemicals (TCs) such as lead, pesticides, and occupational carcinogens in 2019 alone Ordinary people can come in contact with TCs through work environments such as production workers in the pharmaceutical industry and agriculture, contaminated water, and products such as cosmetics, household cleaners, and gasoline. Long-term exposure to TCs can cause cancer, organ failure/damage, or a compromised immune system. Continuous exposure to benzene can cause haematotoxicity that can lead to an increased risk of leukemia as well as gastrointestinal and neurological toxicity. Benzene is found in petroleum-derived products such as synthetic rubbers, polyesters, paint thinners, and gasoline. It is also used in pharmaceuticals, explosives, and herbicides. To protect the lives of employees who risk high exposure, we use a physiologically based pharmacokinetic (PBPK) model and mathematical simulations to determine the accumulation of benzene in the bloodstream over an average work schedule and to understand the consequences of changing variables like concentration level and exposure time on the accumulation of TCs in the bloodstream. We can determine from the results whether the work schedule exceeds benzene's toxic level, effective decontamination methods, and ways to mitigate exposure.

Development of a novel male contraceptive using cyclic peptides to inhibit fertilization

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Abstract: Almost half of all pregnancies are unintended, with more than 60% of these events resulting in termination. Contraceptive options for females dominate the market, with male contraceptive options limited to condoms and vasectomy. Numerous hormonal and non-hormonal male contraceptives are under development; hormonal-based contraceptives that modulate the hypothalamic (GnRH)-pituitary (LH/FSH)-testicular (T) axis are associated with increased susceptibility to carcinogenesis and cardiovascular dysfunction. Non-hormonal male contraceptives aim to limit or inhibit spermatogenesis or sperm function (e.g. fertilization), but often target ubiquitously expressed proteins, have short half-lives in vivo (thus limiting efficacy) and are not readily reversible. *These risks and shortcomings highlight the unmet need for the development of targeted and effective male contraceptives.* Successful fertilization requires the binding of numerous sperm-derived proteins to oolemma-tethered receptors. Thus, the overall objective of the project is to design cyclic peptides that block sperm-derived proteins from binding their cognate oolemmal receptors (Fig 1), and thus inhibit fertilization. Therefore, our specific aims are (i) to rationally design peptides that selectively bind sperm-derived proteins in silico, (ii) validate their efficacy in blocking fertilization using in situ simulations. Successful execution of these aims will provide proof-of-principal evidence that rationally designed cyclic peptides can form the basis of a novel approach to male contraception.

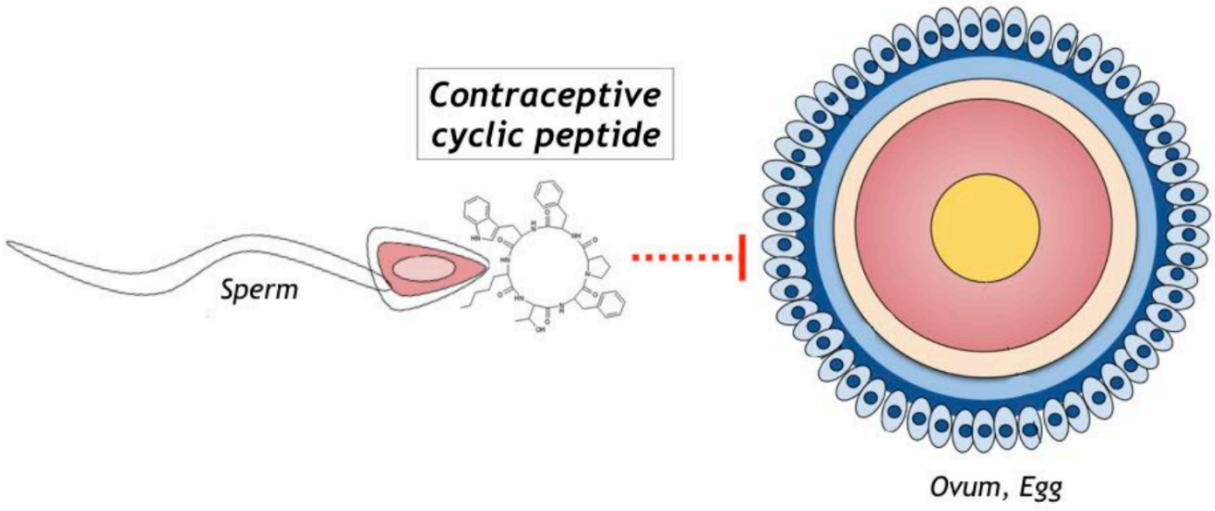

Figure 1: Simulated interaction of designed cyclic peptide with sperm-specific protein preventing fertilization

Design and in vivo analysis of self-assembling peptide hydrogels

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Abstract: Diabetes is a chronic disease characterized by the body's inability to properly regulate blood glucose levels, resulting in hyperglycemia. The 2024 report documented by Harvard University had stated that in 2021, more than 38 million people of all ages (11.6% of the U.S. population) had diabetes, a number projected to double in the next decades and which has a global annual cost ~$250 billion. Wound healing in diabetics is impaired due to a combination of neuropathy, vasculopathy, infection, and other internal and external factors stemming from hyperglycemia and other diabetes-related pathological conditions. Current diabetic wound care involves vascular assessment, infection management, debridement, and offloading, but approximately 20% result in lower extremity amputation. Despite challenges such as immune rejection and poor gene uptake, biomaterials like self-assembling peptide hydrogels (SAPHs) offer promising alternatives to growth factor delivery for wound healing. This project focuses on two self-assembling peptides: angiogenic and antimicrobial peptides, which are synthesized by solid phase peptide synthesis in this very lab and then prepared into hydrogels. These hydrogels are injected into the subcutaneous layer of rodents. The tissue samples are observed on day 7 and 28 and then studied under the inverted microscope and stitched digitally with the help of Photo Affinity 2 software. The slides are then quantified with the help of QuPath Software. Quantification involves analyzing the tissue sections for cell density, neovasculature and the degree of infiltration. It is done to observe any changes introduced by the hydrogels in the system. This would further help in understanding the drug's effects, assessing its potency, and evaluating its other characteristics.

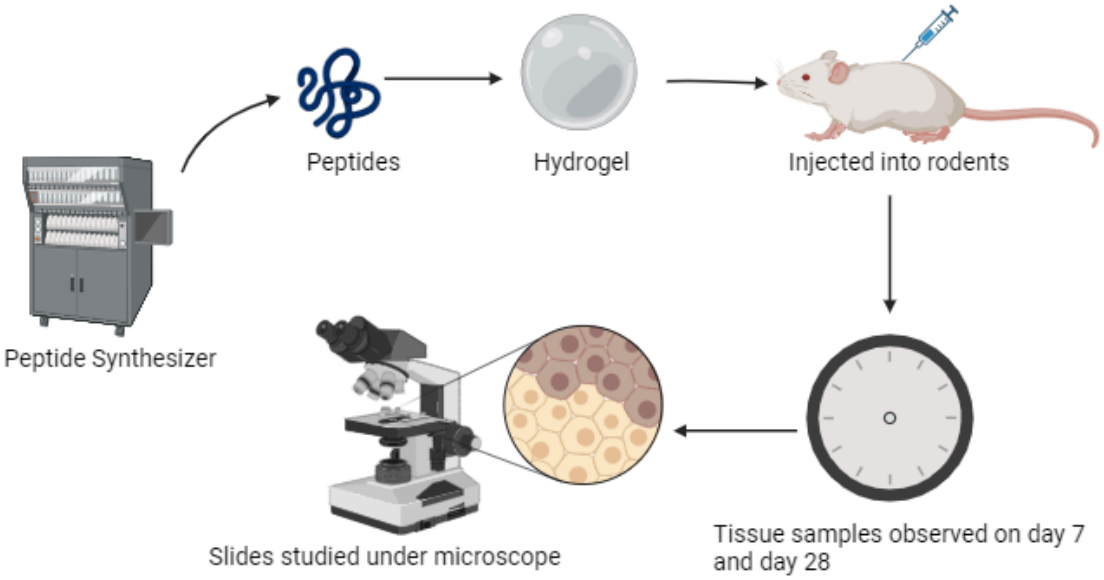

Fig 1: Schematic diagram of synthesis and analysis of peptides

Evaluation of Macrophages for Axonal Growth for Peripheral Neuropathy

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Abstract: Peripheral neuropathy, a common and often debilitating condition affecting millions, is characterized by damage to peripheral nerves. Its prevalence is estimated at a staggering 2.4% globally. The current gold standard for peripheral nerve injury is autologous nerve transplantation which has got various limitations such as neuroma formation and additional injury site formation. Consequently, researchers are investigating various tissue engineering approaches to address these issues. Macrophages, immune cells crucial for wound healing and inflammation, are emerging as key regulators of axonal regeneration after peripheral nerve injury, where M1 macrophages are pro-inflammatory and involved in host defense, while M2 macrophages are anti-inflammatory and play roles in tissue repair and remodeling.

This project investigates the multifaceted role of macrophages in supporting axonal growth in peripheral neuropathy. We will explore how distinct macrophage subtypes, characterized by their unique cytokine profiles, influence axonal regeneration. To investigate the role of different macrophages on axonal growth, we have utilized a 3D *in vitro* collagen gel model with a hollow channel where dorsal root ganglia (DRG) explants isolated from rat embryos were seeded. Culturing these DRGs under controlled conditions allows us to examine how different growth factors and simulated microenvironments influence axonal growth. This *in vitro* model provides a highly controlled environment to dissect the intricate interplay between macrophages (M1 and M2), and axonal regeneration.

Research in this area is challenging due to the dynamic plasticity of macrophages and the difficulty of translating in vitro findings to more complex in vivo models. Despite these challenges, by elucidating the complex interplay between macrophages and cytokine signalling in peripheral nerve repair, this research aims to identify potential therapeutic targets for promoting axonal regeneration and functional recovery in peripheral neuropathy.

Molecular Cloning of Neurodevelopmental Disorder Associated G3BP1 Mutants

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Stress granules (SGs) are phase separated cytoplasmic granules, which contain mRNAs and RNA binding proteins (RBPs) (Protter and Parker 2016, Hofmann, Kedersha et al. 2021, Lindström, Chen et al. 2022). SGs are generally believed to be formed in response to various environmental stresses and act as a protective mechanism to temporarily store non translating pools of mRNAs (Protter and Parker 2016, Dalla Costa, Buchanan et al. 2021, Hofmann, Kedersha et al. 2021). Ras GTPase-activating protein-binding proteins 1 and 2 (G3BP1 & G3BP2) are core SG proteins, which nucleate SG assembly (Yang, Mathieu et al. 2020, Jia, Zhang et al. 2022). Recent findings show *de novo* mutations in SG genes, including G3BP1/2, in various neurodevelopmental disorders (NDDs), and a few of these G3BP1/2 mutants show defective SG assembly in HeLa cells (Jia, Zhang et al. 2022). *Therefore, we hypothesize that dysregulation of SG dynamics and G3BP function may be implicated in the pathogenesis of NDDs*. This project aims to investigate the impact of two mutations in G3BP1 (R78C and R132I), which showed the highest effect on SG assembly in HeLa cells on neuronal cell development (Jia, Zhang et al. 2022). I am performing site-directed mutagenesis to introduce specific the above NDD-associated G3BP1 mutations. Understanding the molecular mechanisms underlying SG formation and G3BP1-mediated pathways holds promise for identifying novel therapeutic targets, thus addressing the unmet needs in the treatment of NDDs.

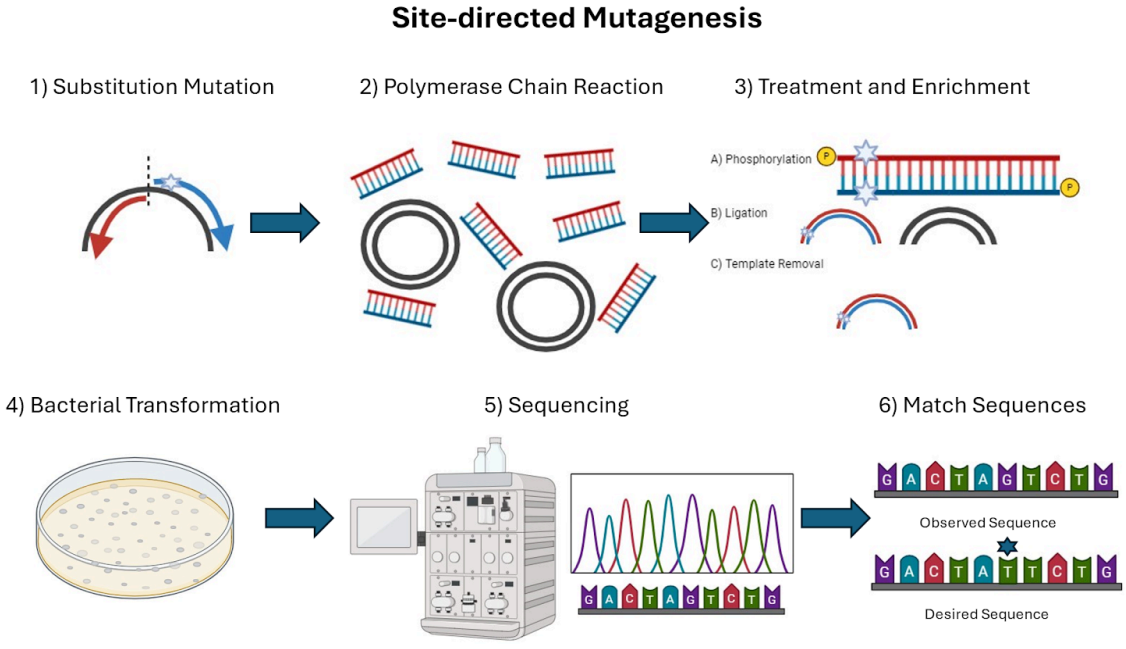

Figure 1: Site-directed Mutagenesis (SDM) and steps to sequencing

Understanding the Mechanism for Handedness Transformation in Eusocial Snapping Shrimp

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Eusociality, the highest form of social organization in animals, is defined by a reproductive division of labor. Eusocial species live in colonies in which a select few engage in reproduction, while others specialize in other tasks. In some lineages, eusociality is a driver of unique body forms to increase group efficiency, resulting in non-reproductive and reproductive individuals that are morphologically specialized. Studying these unique forms and their evolutionary history provides insight into the causes and consequences of obligate group living. Eusociality is most notable and successful in terrestrial insects, with eusocial ants and termites alone accounting for over half of all insect biomass. The only known eusocial marine organisms are within a genus of sponge-dwelling snapping shrimp called *Synalpheus*. This genus contains one-third of all eusocial origins, allowing for rigorous hypothesis testing of the impact of social behavior on organisms. Snapping shrimp are morphologically unique due to their asymmetric claws; one enlarged snapper that is about the length of half of their body, which is used in defense, and one smaller pincer claw, which is used for eating and other minor tasks. If the large snapping claw is lost, the pincer claw on the opposite side of the body will grow and become a new snapper claw, resulting in a change in handedness, a rarely observed ability in crustaceans. To investigate the relationship between this claw reversal process and social behavior, we compared the snapper and pincer claws across several eusocial and non-eusocial species. Volume measurements were collected from 3D reconstructions of micro-CT scans of the shrimp and linear measurements were collected using a stereomicroscope. When comparing the snapper and pincer claws within a sociality type, either eusocial or non-eusocial, similar proportions could illustrate that the two claws are inherently morphologically similar, suggesting a shorter regeneration and claw reversal time. By conducting a dimension reduction technique called principal component analysis (PCA), we identified physical attributes most responsible for morphological diversification in certain species, allowing us to determine if the evolution of eusociality correlates with the development of similar snapping and pincer claws. The aim of this study is to determine whether eusociality has a direct impact on claw morphology across species and provide a foundation for uncovering the claw reversal mechanism. Understanding the causes and effects of eusociality will help us explain unique forms and behaviors observed today and how they shape the evolutionary history of social organisms.

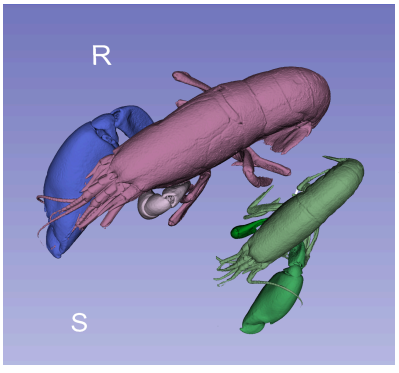

Figure 1: 3D reconstruction of two *Synalpheus bocas*, a non-eusocial species, created using a micro-CT scan. For each shrimp, the body, snapper claw, and pincer claw were individually segmented. Each segment has its own color for visual distinction.

Multiplex Assay Integrated Nanobiochip-based Point-Of-Care (MAIN-POC) Device for Cancer Early Diagnosis

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The United States will face a record-breaking 2 million new cancer cases in 2024, according to the National Cancer Institute. While early diagnosis offers a promising five-year survival rate of 90%, challenges persist due to latent symptoms and complexities of diagnosis at the early stage, which deter patients from invasive and costly screening. Blood-based point-of-care (POC) devices have recently emerged as a prospect for less-invasive early detection, as the slightest molecular change of biomarkers in circulation can predict disease onset in a timely manner. Additionally, efforts to integrate multiplex assay and POC devices for targeting multiple biomarkers offer a promising approach to consolidate reliable early diagnosis into a single, standalone device.

This study aims to enhance the stability and accuracy of the multiplex assay integrated nanobiochip-based POC (MAIN-POC) device. The MAIN-POC device consists of a surface-engineered microfluidic channel that self-separates target biomarkers from finger-prick blood samples and a biosensor array embedded into the microchannel, enabling immediate detection of specific biomarkers via the capacitance variation caused by target antigen-antibody conjugation. In this study, the biosensors' performance was optimized by improving the antibody-electrodes interface and evaluated using indirect fluorescent microscopy to inspect for uniform antibody distribution. Subsequently, the capacitive response to CA-125, an ovarian cancer biomarker, is assessed using controlled samples diluted in PBS and plasma under static-drop and shear-flow conditions. Meanwhile, the flexibility of the optimized sensing interface was tested for detecting multiple biomarkers, such as Aβ42.

The optimized sensing interface that is uniformly coated with antibodies produces more repeatable and accurate measurements. PBS and plasma tests validate the functionality of the biomarker detection in both static and shear flow conditions, ensuring accuracy for biosensing in a blood environment. The adaptability for multiple biomarkers serves to expand the device's potential as a versatile multiplex assay platform for the simultaneous detection of multiple diseases based on their corresponding biomarkers. The outcomes of this study have improved the biosensor performance and expanded detection capabilities, contributing to the future work of refining multiplex utility and applications for broader disease screening.

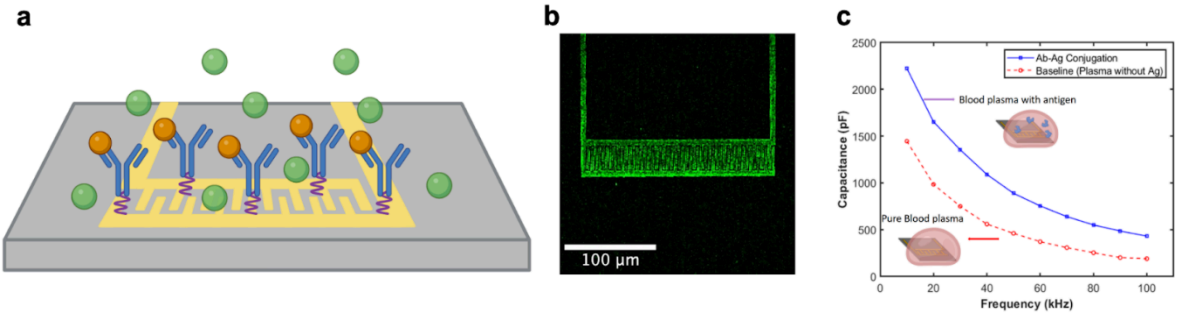

Figure 1: (a) Biosensor electrodes with antibodies (blue) immobilized via polyethylene glycol (purple), capturing target biomarkers (orange) while non-target biomarkers (green) remain unbound. **(b)** Fluorescent microscopy showing interdigitated

electrodes with uniformly distributed immobilized antibodies. **(c)** Capacitive measurements under shear flow conditions demonstrate biosensor specificity for target biomarkers in plasma.

Enhancing Targeted Drug Delivery: The Role Of Protein Corona

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The advancements in medicine have evolved thanks to the progress in the pharmaceutical industry, where methods have been found to administer drugs for diseases while minimizing the risk of side effects. Therefore, there is a focus on studying how the protein corona behaves when it enters a biological body. The protein corona adheres to the surface of nanoparticles upon contact with a biological environment, significantly influencing the biological performance and therapeutic effectiveness of the nanoparticles.

This study is based on understanding the formation of the protein corona and its role in the pharmaceutical industry. We focus on researching the composition of the protein corona, including its size and the biological medium. We use advanced techniques that allow us to study in detail everything required to understand this factor. Techniques such as nanoparticle tracking analysis (NTA) allow observation and measurement of the protein corona under different conditions. Additionally, we compare these results with other techniques like dynamic light scattering (DLS) to evaluate differences in corona formation in various biological environments, such as diluted and undiluted blood plasma. Moreover, factors such as experimental conditions profoundly influence protein corona composition and nanoparticle aggregation, necessitating thorough investigation for optimized drug delivery strategies.

In this study, we also focus on the viscosity that NTA cannot measure, given that we use different types of goat and cow blood plasma with different anticoagulants. Therefore, we use the viscometer in detail with varying amounts of saline and nanoparticles, considering the dilution level and the type of blood used. This helps in understanding the rheological properties of the biological environment and their effect on protein corona formation.

Understanding and manipulating the protein corona, experimental procedures, and plasma viscosity are essential for developing efficient targeted drug delivery systems. This summer research project aims to provide valuable insights into the interactions between proteins and nanoparticles and to establish guidelines for designing nanoparticles with greater therapeutic potential.

Tracking Mechanisms of Phthalate Toxicity in Mouse Ovaries

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Phthalates are plastic additives and a type of endocrine disrupting chemical (EDC). These compounds are hypothesized to mimic the structure of hormones and bind to nuclear receptors. They have widespread use as additives to plastics to improve flexibility and durability. As they are not covalently bound to the plastic, phthalates easily leach out into the environment, resulting in ubiquitous human exposure . Studies have shown that women, especially those of reproductive age, have increased urinary phthalate metabolite levels compared to men. This is extremely concerning as long term exposure to phthalates is associated with changes to reproductive processes such as changes to sex steroid hormone levels, infertility, and miscarriage. It is not well known which hormone receptors are the targets of phthalates. Therefore, the goal of this project is to screen for binding between the compound and receptors. In this project we will synthesize a phthalate which can be tracked within a living system with the goal of identifying the mechanism of the toxic effects phthalates have on ovaries. The phthalates used will be synthesized to include an alkyne group allowing for click chemistry via highly specific binding of fluorescent probes and tracker molecules. We will use our modified phthalates in a method known as chem-seq that is used for determining the relevant mechanisms of small molecules. This project will allow us to determine the mechanistic pathway of phthalates by determining what receptors they bind to and what DNA motifs the phthalate-receptor complexes bind to once inside the nucleus of a cell. Overall, this project will advance knowledge on EDC mechanisms of action, which is crucial for determining the safety and regulation of these compounds.

Uterine Cancer Image Analysis with Convolutional Neural Networks

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Abstract: Endometrial cancer is a deadly disease that affects thousands of women each year, with a disproportionate mortality rate in black women compared to other racial groups. This discrepancy can be partially credited to the fact that it is often diagnosed in a later, less treatable stage in black women. A certain portion of this diagnostic differential can be explained by human bias and errors. Artificial intelligence and machine learning (AI/ML) can be used to compensate for this human element. Convolutional neural networks (CNNs) are an advanced form of ML that has shown promise in medicine, accurately performing diagnoses and medical image analysis. A key advantage of CNNs is that they require less manual image preprocessing compared to other ML techniques. The main issue with CNNs is that they require immense datasets to be trained from scratch, but repurposing pre-trained CNNs and artificially expanding the dataset cut down the required data collection. This study uses pre-trained CNNs to distinguish images of different types of uterine cancer and different racial groups and evaluate those models for racial biases. Exploring the capabilities of AI/ML for diagnostic purposes allows for the minimization of human biases, potentially saving lives and improving care.

MEP Latency Dynamics in Low Cortical Excitability with Novel Paired-Pulse TMS Protocol

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Stroke rehabilitation is a critical area of medical research due to the high prevalence and severe impact of stroke-related motor impairments. This project aims to investigate the efficacy of a novel paired-pulse transcranial magnetic stimulation (TMS) protocol within brain state-dependent paradigms for stroke rehabilitation. Specifically, we seek to determine whether the proposed paired-pulse TMS protocol, delivered during mu-oscillation troughs, elicits motor-evoked potentials (MEPs) with significantly faster latency and larger amplitude than the conventional single-pulse protocol. The primary goal is to demonstrate the superior efficacy of the paired-pulse protocol in enhancing neural excitability, potentially offering a breakthrough in neurostimulation techniques for stroke-related motor impairments.

This study involves three groups of healthy adult participants: one group undergoing the conventional single-pulse TMS protocol and the other undergoing the novel paired-pulse protocol, and one placebo group. Participants are randomly assigned to these groups. During the sessions, participants are connected to EEG to monitor real-time brain activity and EMG to record muscle responses from a peripheral hand muscle. The primary aim is to examine differences in MEP latencies and amplitudes when administering single and paired TMS pulses during mu-oscillation troughs.

Participants will be blinded to the protocol they receive. The study aims to recruit 3-6 healthy volunteers (one/two for each protocol) from the local community, adhering to specific inclusion and exclusion criteria. Approval for the study has been obtained from the NJIT Institutional Review Board (Protocol number: 2303032088).

We anticipate that the paired-pulse protocol will demonstrate shorter MEP latencies and larger amplitudes compared to the single-pulse protocol, indicating more efficient activation of the motor cortex. This could highlight the paired-pulse protocol's potential in enhancing neural excitability and improving motor recovery outcomes for stroke patients.

The results of this study could pave the way for more effective TMS-based rehabilitation protocols tailored for stroke survivors. Future research may involve testing the paired-pulse protocol on stroke patients to directly assess its clinical efficacy and exploring its applicability to other neurological and psychiatric conditions. This project aims to contribute to a significant advancement in neurostimulation techniques, potentially leading to better clinical outcomes and improved quality of life for individuals with stroke-related motor impairments.

Assessment of DNA Profiling From Remains Exposed to Different Conditions

Maya Hassan[1], Advisor: Dr. Sara Casado Zapico[2], Mentor: Maria Castagnola[2], Ph.D. Student

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New Jersey Institute of Technology, Newark NJ 07102
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Abstract: The identification of human remains is critical in criminal investigations, mass disasters, and humanitarian settings. However, obtaining DNA for identification from these remains is challenging due to exposure to different insults: fire, chemicals, and environmental factors. Additionally, estimating the postmortem interval (PMI) – the time since an individual's death – could also be important to pursue the investigation. New approaches in forensic biology and anthropology introduce next-generation sequencing technologies, transcriptomics, and proteomics as more accurate methods for determining PMI, particularly in human remains. The goal of this study is to assess the feasibility of extracting DNA, RNA, and protein from human remains exposed to fire and chemical treatments, aiming to facilitate identification and PMI estimation. To do so, sample extraction was performed using Quick-DNA/RNA Microprep Plus Kit (Zymo) on samples from 18 whole human teeth (18 dentin and 12 pulp) subjected to hydrochloric acid (HCl) and sodium hydroxide (NaOH) treatments, alongside respective controls. Additionally, 24 samples of powdered human bones underwent treatments including exposure to fire, HCl, and NaOH, compared to control powdered bones. Quantification of DNA/RNA/proteins was performed using spectrophotometric and fluorescence methods. Human DNA profiles were generated using the Promega® Fusion 6C System. In both whole teeth and bone powder samples, DNA, RNA, and proteins were successfully extracted in the majority of cases. In whole teeth, higher yields of DNA, RNA, and proteins were found in control samples compared to chemically treated ones. Specifically, DNA concentration was consistently higher in pulp than in dentin across all groups. Significant yields were also obtained for RNA and proteins, with variability depending on the treatments. Particularly, the HCl treatment yielded the highest levels of DNA, RNA, and proteins for teeth. Conversely, in bone powder samples, NaOH treatment yielded higher amounts of DNA and RNA than the HCl treatment, contrasting with teeth samples. Successful extraction of DNA, RNA, and proteins was achieved from burned bone powder, with DNA showing the highest yield. The successful extraction of DNA from human bone remains exposed to fire aligns with findings from a previous study conducted by Zapico et al. 2016. The extraction of DNA is fundamental for generating profiles for individual identification. Additionally, RNA and protein yields obtained from this work hold promise for estimating the postmortem interval (PMI). To the best of our knowledge, this is the first extensive study assessing the simultaneous extraction of DNA/RNA/proteins from human remains exposed to different insults. In most cases, DNA/RNA/protein material from fully fleshed corpses could be better preserved within the human body than in the analyzed bone remains that were completely exposed. The findings of this research studying the worst-case scenario could significantly aid in identifying human remains in challenging cases like mass disasters.

Design of Novel Auto-Immune Antibody-Binding Peptides In Silico

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Multiple sclerosis (MS) is a chronic autoimmune disease caused by the degradation of the myelin sheath, a structure that promotes the survival and function of nerve cells in the central nervous system. This degradation, or 'demyelination', is in part caused by immune cells which regulate the release of pathologic antibodies that target the myelin sheath. Therefore, to alleviate the effects of autoimmunity in MS patients, numerous therapeutics indiscriminately deplete whole or partial immune cell populations. Although effective in some patients, broad spectrum immunosuppression can render patients susceptible to serious secondary risks of opportunistic infection and cancer. This highlights the unmet need for new MS therapeutics that specifically target the biological underpinnings of disease.

The overall research objective of the lab is to utilize artificial intelligence, machine learning, and in silico peptide docking platforms to resolve protein and peptide structures for the design of novel therapeutics that specifically target disease whilst not being widely immunosuppressive. Specifically, the research will employ the computational software platforms Rosetta Scripts and Nanoscale Molecular Dynamics (NAMD) for high-performance, atomic-level interactions and analyses of therapeutic peptides binding to protein targets. Additionally, it will make use of visualization platforms such as PyMOL to represent these interactions, for the design of promising therapeutic peptides. Using these analytic platforms, peptide-protein interactions will be simulated with the aim of designing a peptide that will be able to most aptly bind to the harmful antibodies and prevent their attack on the myelin sheath. These simulations will allow for analysis that can identify options for peptides that can be used as treatment. Successful execution and analysis of these simulations will provide critical support for the clinical relevance and application of our therapeutic platform to treat patients suffering from MS and other autoimmune diseases.

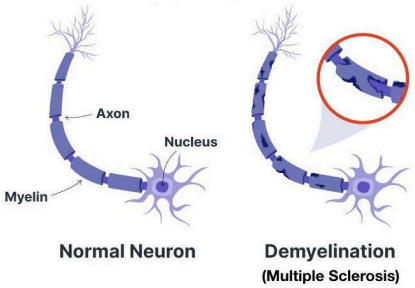

Figure 1: Demyelination

pH-Responsive Oligomers for Targeted Nucleic Acid Therapy

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Abstract: Gene therapy is a rapidly growing field with the potential to treat a variety of viruses, cancers, and other illnesses, so designing effective delivery vectors can revolutionize the efficacy of treatment. Polymer delivery vectors can be synthesized with specific sequences and chemical groups to target different tissues or organs in the organism, based on the properties of the polymers. In this project, poly-α-amino esters (PAAEs) will be synthesized with added electron-donating groups, which change the pKa, or strength of acidity, of the polymer. The building blocks for each PAAE will be synthesized, and then iterative exponential growth (IEG) will be utilized to synthesize polymers with different sequences of building blocks with electron-donating groups. The pKas of these polymers will be determined through titration, and their efficacy at gene delivery can be tested by complexing the polymers with Fluc-mRNA and measuring their transfection in cell cultures. We hypothesize that changing the acid strength of the delivery vector by adding electron-donating groups and changing their sequence will cause the polymer to become pH-responsive, thus allowing genetic material to be delivered to tissues with a specific pH. Tumor tissue pH is markedly more acidic than normal physiological pH, so gene therapy for cancer treatment could be made more efficient by designing polymers with the optimal pKa for tumor environments.

MCC950 as a Therapeutic for Inflammation in Blast-Induced Traumatic Brain Injury (bTBI)

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With over 110 armed conflicts occurring around the world today, the incidence of blast-induced traumatic brain injury (bTBI) continues to rise. bTBI refers to brain damage caused by exposure to shockwaves generated by an explosion. Soldiers and civilians suffer detrimental primary and secondary injuries such as inflammation, oxidative stress, and neuronal cell death from exposure to repeated low-level blasts (rLLB). Evidence also suggests that traumatic brain injuries (TBI) increase the risk of developing psychiatric disorders with neuroinflammation acting as a primary mechanism for increased neuropsychiatric symptoms. However, while there is no known treatment to mitigate these effects, one promising method of limiting the occurrence of secondary injury is by targeting neuroinflammation. One of the primary inflammatory mediators involved in neuroinflammation, the NLRP3 inflammasome, serves as a potential target for treating inflammation in the brain. MCC950, a selective inhibitor of NLRP3, may attenuate activation of this inflammasome, thereby reducing neuroinflammation and associated neuropsychiatric abnormalities in bTBI. To determine whether MCC950 can reduce inflammation and decrease the risk of psychiatric abnormalities in bTBI, mice will be exposed to a rLLB and treated with MCC950. Anxiety behavioral tests will be conducted 1 day and 30 days post-injury and immunohistochemical techniques will be used to stain sectioned brain samples of the mice to mark the activity of microglia and quantify the inflammation. Significant differences between the inflammatory responses and psychiatric symptoms of untreated and treated individuals will be analyzed to examine the effectiveness of MCC950 in reducing blast induced neuroinflammation and related behavioral changes. Bridging the gap between the biochemical and psychological aspects of bTBI research, this project offers a therapeutic approach for addressing secondary injury driven by blast-induced neuroinflammation.

EGFr Binding Peptide Contrast Agents for Signaling EGFr-Positive Tumors

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Abstract: Triple Negative Breast Cancer, TNBC, is an aggressive and fast-growing subtype of Breast Cancer, which lacks an established therapeutic target. It is characterized by the absence of increased expression of the estrogen receptor, progesterone receptor, and human epidermal growth factor receptor 2 (HER2). Additionally, TNBC affects 13 in every 100,000 women in the United States. Magnetic Resonance Imaging, MRI, is the main noninvasive method to detect these tumors. However, due to TNBC's unique characteristics and nonuniform shape, it is more likely to have inaccuracies in the diagnosis of the tumor and/or tumor morphology. A gadolinium-based contrast agent chelated by an Epidermal Growth Factor Receptor (EGFr) binding peptide is being developed to address these limitations in MRIs. The use of this conjugate will improve the contrast in MRI scans, leading to more accurate detections of EGFr-positive tumors, such as the most common subtypes of TNBC. The conjugate will bind to EGFr, where the paramagnetic gadolinium ions will interact with water molecules in tissues, influencing relaxation rates on MRI scans. EGFr-binding peptides were synthesized by Solid-Phase Peptide Synthesis and coupled with a chelating agent. The main peptide, AEGFr, was found in previous literature and was linked to self-assembling peptides previously developed in KumarLab to develop novel self-assembling multidomain peptides K1-G-AEGFr and E1-G-AEGFr. The peptide conjugates were synthesized and characterized for their chemical, structural, and mechanical properties. The affinity of self-assembling conjugated peptides to the EGFr needs to be further tested with Microscale Thermophoresis, MST to find the best binding affinity. Next, the peptide conjugates are combined with a gadolinium(III) ion solution. The peptide will then self-aggregate to form a translucent soft hydrogel. The formed EGFr Binding Peptide Contrast Agent can then be injected into a patient, increasing the accuracy of EGFr+ tumor diagnosis.

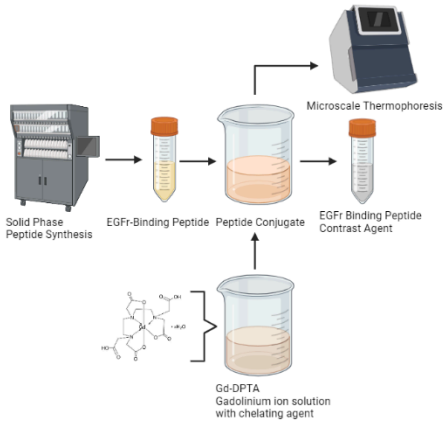

Figure 1: Schematic of Experimental Procedure. Created with BioRender.com

Electromagnetic Field Effects on T47D (Breast Cancer) and MCF-10A (Healthy) Cells

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Abstract: Breast cancer is the second leading cause of death for women in the U.S., with 43,250 reported fatalities in 2022. Conventional treatments, such as chemotherapy, radiotherapy, and surgery, have severe side effects impacting both the physical and emotional well-being of patients. Electromagnetic fields (EMFs) offer a potential non-invasive treatment option that could effectively treat breast cancer while reducing the negative impact on patients. However, it is crucial to ensure minimal to no harm to healthy cells to avoid severe long-term side effects. This research project aims to design an EMF device that negatively affects breast cancer cells while keeping healthy cells safe. Therefore, a Helmholtz coil (as illustrated in Figure 1) was designed with air cooling running through the coils to prevent temperature rise and ensure stable current flow, mitigating heat-induced effects. Air cooling also allows precise temperature control, maintaining conditions at, below and above body temperature. Past experiments show a noticeable decline in cell life for T47D cells. However, following experimentation at body temperature (37˚C) using three distinct intensities (0.14A, 0.7A, and 1.45A), no decline in T47D cell viability was observed through imaging and cell count analysis. This shows that past experiments were conducted at temperatures different from body temperature, which can be a potential reason for T47D cell deaths. Nevertheless, this does not eliminate the fact that a stable temperature can be achieved that can eliminate T47D cells while still keeping healthy cells safe. Future experiments will be conducted in a microfluidic setup to provide cells with a more controlled thermal environment, aiming to eliminate T47D cells while preserving healthy ones. Furthermore, anticipated outcomes include measuring the metabolic rate of the cells while in the field to better understand the mechanisms at play.

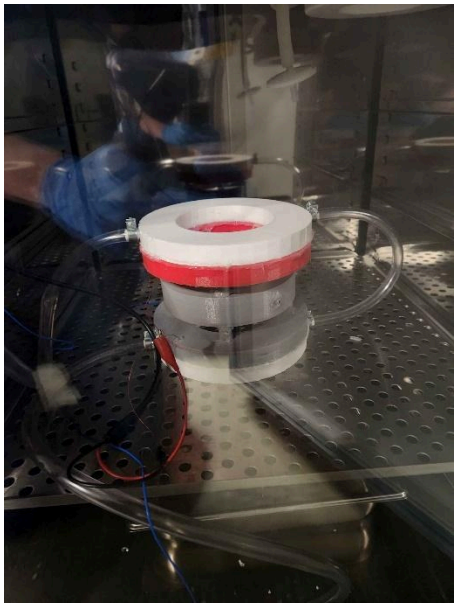

Figure 1: Helmholtz coil configuration featuring 500 turns of 24-gauge copper wire per side, equipped with air cooling tubing.

Formulation of stable and functional recombinant protein stabilized phase shift nanodroplets for ultrasound theranostics

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Phase-shift nanodroplets (PSNDs) are ultrasound theranostic agents that image and treat diseases like cancer and deep vein thrombosis. When high-intensity focused ultrasound (HIFU) is applied, the internal nanodroplet liquid core vaporizes – this can cause mechanical disruption of tumor cells via cavitation and release of encapsulated drugs. It is essential to target PSNDs to specific cells. Traditional PSNDs use lipid-PEG surfactants as stabilizers, presenting challenges during peptide/protein functionalization. We will introduce a novel PSND formulation using recombinant proteins, specifically oleosin. Oleosin is an amphiphilic protein our lab has genetically modified to produce functional molecules that can self-assemble into micelles/vesicles. Unlike lipid functionalization protocols, recombinant proteins can be made to express any functionality without needing post-formulation conjugation, separation, and washing steps while ensuring uniformity across all molecules produced – by simply inserting the relevant plasmid into bacteria. We aim to use oleosin to stabilize and functionalize nanodroplets so that they can be recognized by tumor cells. RGDS will be cloned into the oleosin molecule to produce Oleosin-RGDS protein – this will serve as a proof-of-concept for demonstrating selective droplet uptake into cancer cells. In summary, we will show the feasibility of recombinant-protein stabilized, ultrasound-responsive PSNDs for imaging, tissue ablation, and drug delivery.

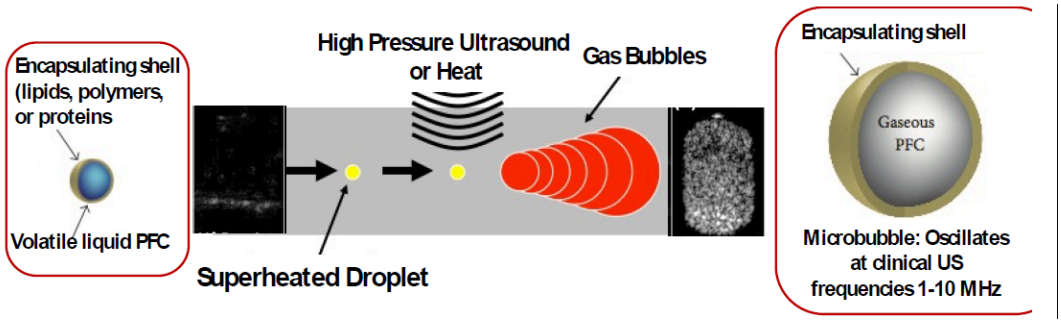

Figure: Vaporization of droplets into bubbles via HIFU. The grainy image on the right is the ultrasound signal from the bubbles and droplets, before vaporization, but no ultrasound signal is shown (black image on the left).

Designing a Peptide Ligand for a Novel Cancer Therapeutic

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Mentor : Joseph Dodd-o[2]**, PhD student**
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Abstract: Globally, 500,000 women die annually from breast cancer, of which 150,000 cases are estimated to be of the Triple Negative Breast Cancer (TNBC) staging subtype. TNBC is an aggressive type of breast cancer that lacks the Estrogen (ER), Progesterone (PR), and Human Epidermal Growth Factor (HER2) receptors. There is a lack of targeted therapies available for TNBC, as current endocrine and drug therapies that target ER, PR, or HER2 are ineffective. Sigma 2 receptors are overexpressed in proliferative cells and tumors, especially breast cancer cells. The aim of this study is to computationally randomize amino acid sequences that bind to the sigma 2 receptor to make a cytotoxic drug. By utilizing the Rosetta Scripts software, an XML-like language used for parsing functions within the Rosetta suite, 4,000 different amino acid sequences that bind to this receptor were generated. The top ten unique sequences with the lowest binding energy were then used for further analysis. Using the FlexPepDock docking protocol, PackRotamersMover, and relaxation algorithms, one thousand different amino acid sequences were generated. The top 10 most energetically favorable structures were further analyzed by their Root Mean Square Deviation (RMSD) relative to the top-scoring pose to evaluate the potential entropic penalty of adopting the energetically favorable pose. By analyzing the RMSD values and corresponding energy scores, the top three peptides were then chosen to synthesize and characterize to further test for cytotoxicity and affinity.

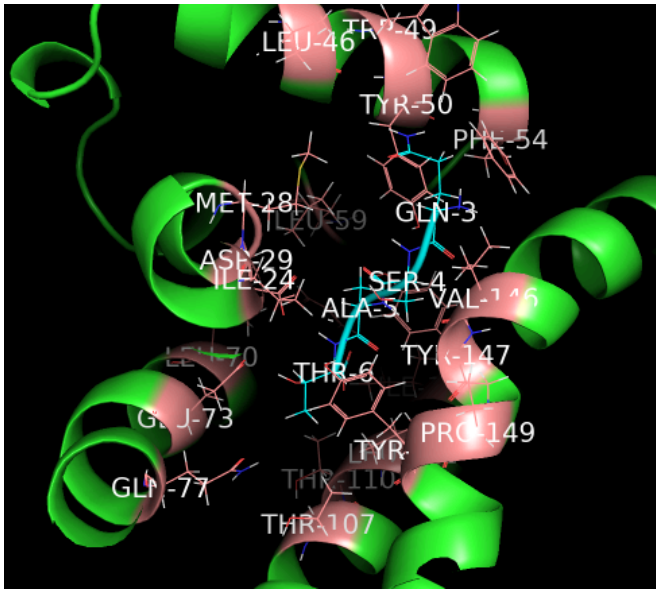

Figure 1. Ligand QSAT (blue) computationally sequenced and docked with the sigma 2 receptor (green). Interacting residues are shown (pink).

Point-of-Care Device for Zoonotic Disease Detection

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Abstract: The urgent demand for more accessible, low-cost sensors capable of detecting zoonotic illnesses in point-of-care settings necessitates novel, inventive approaches. This proposal intends to develop a system for multiplexed detection of disease biomarkers using the ESSENCE platform in a cost-effective and efficient manner. This method involves using target-specific transducer materials sandwiched between non-planar interdigitated electrodes to effectively capture and detect biomarkers. This project intends to create a completely automated and portable sensing system that combines automated fluid flow and electrochemical data collecting operations, all powered by onboard resources. The goal of creating a completely automated system will be accomplished by integrating commercial microfluidic control systems and pocket potentiostat modules with open-source programming languages such as Python. This enables more accessible scaling-up opportunities once in-house systems can replace the commercial modules. The envisioned solution offers a user-friendly, point of care sensor solution for zoonotic diseases, providing a viable alternative to the current single-use or laboratory based tests.

Piezoelectric Needle For Guided Tissue Targeting

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With the rise of cancer-related deaths, biopsy procedures have become crucial for diagnosis, treatment response, and guiding therapy. Needles for biopsies of tumor tissue can be guided by ultrasound or CT. However, these methods have limitations, including limited accuracy and utility with smaller lesions, human error, wrongful needle placement, radiation exposure, and the risk of accidental spread of cells, leading to false negatives and poor tissue samples. Healthy and diseased tissues exhibit differences in mechanical properties, with healthy tissue typically having lower stiffness and tumorous tissues being more rigid. Cancerous tissue can significantly alter the mechanical properties of the surrounding tissue, which can be quantified using Young's modulus to distinguish between healthy and diseased tissues. This approach involves a piezoelectric needle-shaped device, which leverages the piezoelectric effect to generate an electric charge due to mechanical stress, enabling precise targeting of tumor tissue. The device aims to measure tissue stiffness accurately to distinguish between healthy and cancerous tissues, addressing limitations of traditional biopsy methods such as limited accuracy and human error. The ultimate goal is to create a more accurate and less invasive method for cancer diagnosis, improving the characterization of disease states and assisting in the progression monitoring of cancer.

Effects of the Ablation of the Lateral Line System on Collective Fear Responses of Larval Zebrafish *Danio rerio*

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Mentor: William Botta
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Abstract: Mass panic is the communicable spread of distress among a group or population. Studying mass panic in larval zebrafish allows us to analyze the neurobiological factors that contribute to catastrophic mass panic events such as the stampede of Astroworld in Houston, Texas or the suffocation of animals in intensive farming conditions that are kept in tight conditions to meet the dietary needs of the growing population of humans. Studies have shown that in confined high-density environments, larval zebrafish have been known to exhibit circling behavior around the confined space. These panic-like behaviors are exacerbated in dark environments; zebrafish are unresponsive to visual stimuli in the dark. In addition to their visual system, zebrafish also have a lateral line system (LLS), which senses changes in the movement and direction of the water surrounding them (Figure 1). We use four different treatment groups to test the effects of the LLS on collective panic-like behavior: light environment with LLS intact, dark environment with LLS intact, light environment with LLS ablated, and dark environment with LLS ablated. It is anticipated that in dark conditions and with their LLS ablated, the larval zebrafish will not be able to elicit collective panic-like responses given their inability to see and physically sense the movement of their conspecifics. In a 6-well culture plate, 5-6 days post-fertilization larval zebrafish will first be placed in a stock solution of 0.05% DASPEI to stain their lateral line. Once the LLS is visualized, the larval zebrafish will be transferred to a well containing 500 μM solution of neomycin sulfate, where the LLS will be ablated. With the use of a custom behavior rig, behavioral responses of the larval zebrafish will be recorded for the control and ablated groups in videos of 200 frames per second for 10 minutes. Using custom Julia Programming Language scripts, videos will be analyzed using optical flow to determine the movement intensity of the pixels in the images. Comparisons will be made between treatment groups to determine the impact of LLS to generate panic-like responses.

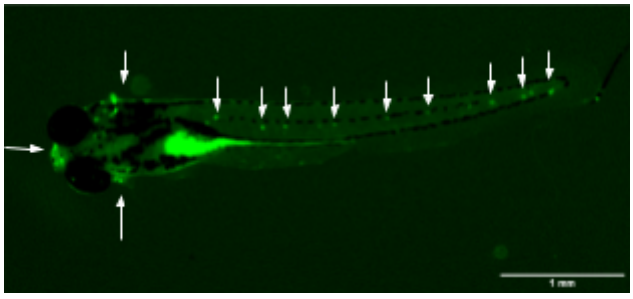

Figure 1. Image of the lateral line system of a larval ABWT zebrafish following DASPEI staining under GFP imaging filter. Neuromasts are the simplest functional unit of the lateral line system. The green fluorescent dots located in the rostral portion of the larval zebrafish are known as the anterior lateral line system and those running along the length of the larval zebrafish's body are known as the posterior lateral line system.

Who Dunnit? Evaluation of Biological Evidence for Crime Scene Reconstruction

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Abstract: On average, there are 433,648 victims of sexual assault in the United States each year. The identification of body fluids at crime scenes is vital as it allows investigators to establish a sequence of events, reconstruct the actions and movements of individuals involved, and eventually to identify suspects and, and sometimes, the victims. Serological assays, based on antigen–antibody reactions, represent one of the most rapid and highly specific tests for the identification of body fluids. The most common and quickest serological tests are the ones based on lateral flow immunochromatography (LFI) tests. LFI tests for semen are based on assessing the presence of prostate-specific antigen (PSA), a protein produced in considerable significant quantities only by prostate. When semen is present in a forensic sample, and as a result, PSA, an antibody-antigen reaction occurs forming an antibody-antigen complex. As this complex travels through the test strip, it is captured by immobilized antibodies forming a line visible to the naked eye indicating a positive result. The test results performed in this project were ranked on a scale from 1 to 10, where 1 indicates a negative result and 10 is a strong positive. The present work evaluates the sensitivity of the SERATEC® PSA Semiquant test kit, an immunochromatographic rapid test designed to detect PSA in biological evidence potentially encountered at crime scenes involving sexual assault cases. For the purposes of this study, human urine samples from males and females were used. Pure, undiluted samples were evaluated on the scale. A series of dilutions were also performed and evaluated to be able to determine the threshold of sensitivity statistically. Female samples were not positive for PSA. With respect to male samples, initial findings suggest that samples can withstand several series of dilutions (1:2, 1:8,1:16) while still being able to produce positive results. Only 3 samples consistently produced results of 10. The same samples were also able to produce strong, visible lines after being diluted to 1:100, where other samples no longer produced positive, visible results. Future research will expand the results, assessing PSA immunochromatographic test sensitivity in other body fluids.

Methylmercury Degradation by *Mycobacterium dioxanotrophicus* PH-06

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Mercury manifests itself in three forms: organic, inorganic, and elemental. Of these three forms, organic methylmercury, MeHg, is by far the deadliest because it can bioaccumulate and biomagnify in food webs. Exposure to high concentrations of MeHg either through direct exposure or through indirect exposure due to the consumption of contaminated food, notably fish, can result in damage to the internal organs, neurological damage, and in some cases death. Methylmercury does not readily degrade and is considered a persistent contaminant. It is crucial for human health that a low-cost, safe, and effective method of demethylating MeHg is found. The use of microbes has proven itself to be safer to human health, and more sustainable in the long-term than other chemical processes. No prior studies have examined the use of *Mycobacterium dioxanotrophicus* PH-06 for MeHg degradation, a bacterium with great potential as it has been used to degrade other contaminants, such as 1,4-dioxane. In this study, experiments were performed to investigate the reactions between MeHg and PH-06. Elemental mercury levels after reaction were measured using cold vapor atomic absorption spectrophotometry, and levels of MeHg were measured using cold vapor atomic fluorescence spectrophotometry. Kinetics experiments show that MeHg at initial concentration of 1 ppb was degraded more than 50% after 72 hours (Figure 1). Use of PH-06 filtrate did not yield any production of elemental mercury, suggesting that the degradation of MeHg is an intracellular process. Further study will be conducted to investigate the mechanisms involved in MeHg degradation by PH-06 and to develop biological MeHg remediation method.

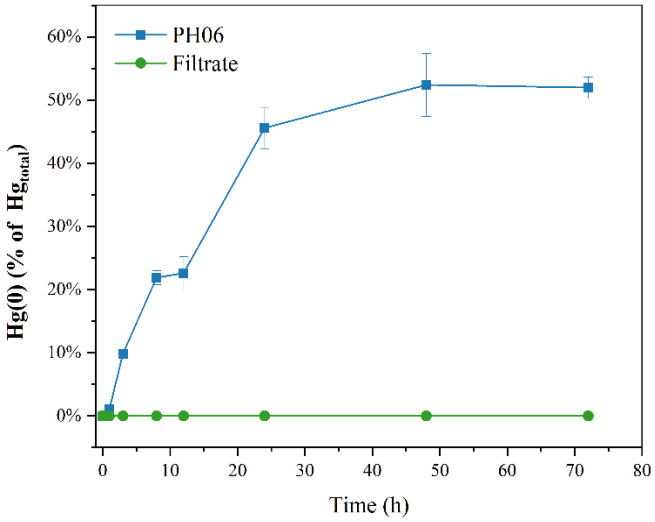

Figure 1. Hg(0) as a percentage of total Hg after reacting MeHg with PH-06 suspension and PH-06 cell filtrate with respect to time (measured in hours).

Analytical Software Technique for Determining the Natural Frequencies of Pupillary Responses in Vergence Eye Movements

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To make a single and clear image the brain needs various visual cues to appropriately rotate (vergence) the eyes inward (convergence) or outward (divergence). The pupil plays a role in general vergence movements for the transition to near vision tasks, with convergent eye movements seeing constriction of the pupils, and divergent eye movements seeing dilation of the pupils. Pupil constriction leads to a sharpening in vision, while dilation blurs vision. Persistent post-concussive symptoms (PPCS) occur when the symptoms of a mild traumatic brain injury (mTBI) persist for at least 1 month, and can manifest as a binocular vision dysfunction known as convergence insufficiency (CI). PPCS-CI is characterized by poor binocular coordination during convergent eye movements. Commonly reported symptoms of PPCS-CI are doubled, blurred, or haloing vision, headaches, photosensitivity, and visual fatigue. The comorbidity of PPCS-CI following PPCS is approximately 38-49% in children and young adults.

This study aims to develop an analytical technique to perform frequency analysis of pupillary responses between patients diagnosed with PPCS-CI and individuals with binocularly normal vision (BNV). Understanding the differences in pupillary frequencies during convergent eye movement can aid in identifying PPCS-CI through the existence of diminished, heightened, or introduced amplitudes within fast-fourier transform (FFT) frequency spectra compared to BNV FFT spectra. These analyses can also aid in determining if current standards of care remediate these frequency characteristics alongside symptoms.

A total of 25 BNV and 27 PPCS-CI participants were analyzed, aged 18.7±1.7 years and 17.7±3.4 years respectively. **Figure 1.** provides the resultant cohort-level FFTs between PPCS-CI and BNV participants for a 4-degree convergent eye movement. Observed are heightened amplitudes within the average BNV FFT spectra compared to the PPCS-CI FFT spectra. The difference of these spectrums depict a greater amount of slow fluctuations in pupil diameter within the BNV participants. These differences in pupil frequency behaviors between cohorts could explain a potential reasoning for why PPCS-CI participants have a shared common symptom of photosensitivity.

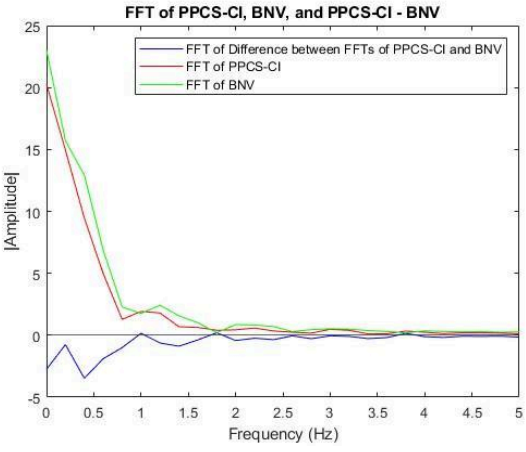

Figure 1: Cohort-level FFT spectra are shown above for each cohort as the summation of the FFT spectra of each participant. A contrast in the FFT spectra is also depicted by the difference in average FFT amplitudes between BNV and PPCS-CI per frequency (Hz).

Future work will focus on expanding the number of samples within the BNV and PPCS-CI cohorts to create more representative normative comparisons models. Furthermore, development of power density spectra for each cohort could generate "fingerprint" peaks, or deficits, of various low-frequency oscillatory frequencies within BNV or PPCS-CI responses to describe instability, or correlate with participant reports of photosensitivity. These supplemental analyses may elucidate instability in the pupillary responses, or potential asymmetry caused by poor binocular coordination, and contribute further to our understanding of the systemic effects of PCCS-CI.

Establishing an assay for visual desensitization in larval zebrafish for understanding synaptic plasticity

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Abstract: Synaptic plasticity, an ability of neurons to modify their strength of connections that occur at synapses, is very important in the visual desensitization in larval zebrafish as it is a form of neural learning. Visual desensitization sheds light on the mechanisms underlying this form of learning and its impacts on the escape response behavior. Based on an established understanding of sensory processing and neural circuitry in zebrafish, we developed a novel experimental setup tailored to investigate visual desensitization. By forming control and experimental groups, we compare larval zebrafish responses to varying intensities and frequencies of visual stimuli mimicking looming threats. Real-time tracking through high-speed cameras and specialized software enables precise behavior assessment, revealing discernible changes suggestive of desensitization upon repeated exposure to weaker stimuli. The next steps will further this research by using closed-loop tracking in order to get more spatially and temporally precise responses. We expect desensitized larvae to reduce their response rate to threatening stimuli. By furthering knowledge on the mechanisms governing sensory-motor transformations and behavioral adaptations, this research contributes to our understanding of fundamental principles of learning and neural plasticity across vertebrates. In the long term, insights from this investigation hold potential implications for clarifying mechanisms underlying neurological disorders and finding new strategies for their management.

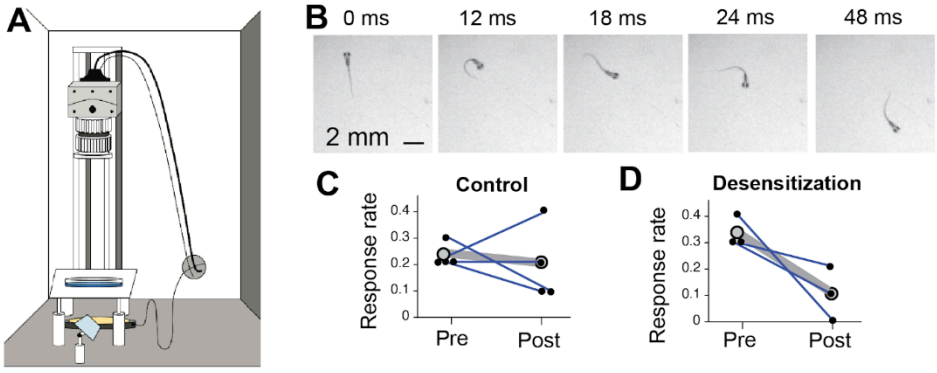

Figure 1. A) Severi Lab custom-built behavior rig schematic (Zaki et al., 2021). The rig includes a platform for the arena containing the fish, an infrared LED array to illuminate the fish, a mirror and projector to project the visual stimulus to a screen below the arena, a high-speed camera fitted with an infrared bandpass filter to visually isolate the fish from the stimulus. The rig is housed in an enclosed box. We will adapt this existing rig by establishing the ideal visual stimulus and arena shape for the desensitization assay. Visually-induced escapes and desensitization B) Raw video frames during a loom-induced escape trial. C-D) Escape response rates following rest (control) and visual desensitization (low contrast) demonstrate this form of plasticity in larval zebrafish for the first time.

Factors Associated with Research Productivity and National Institutes of Health (NIH) Funding in Academic Rhinology

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In this study, we aim to see if the *h-index* or more contemporary bibliometrics such as mean and weighted relative citation ratio (RCR) are better time and field-independent indicators for scholarly productivity within academic rhinology. The objective is to analyze which research productivity metrics result in NIH funding. Moreover, we expect to identify factors, such as gender and location, associated with academic rhinology that can highlight inequalities within publications and funding. The demographics are collected from institutional faculty profiles, and funding data is obtained from the NIH Research Portfolio Online Reporting Tools Expenditures and Reports Database. Bibliometrics are collected and cross-referenced using Scopus and the NIH iCite tool.

Due to the RCR's distinct co-citation network, evaluating it in different fields is important, and benchmark data in academic rhinology is currently lacking. On top of this, an association between RCR and NIH funding remains unclear, and our research aims to help clarify this. Understanding this correlation is of utmost importance as researchers and policymakers can assess the efficiency and impact of funded projects in rhinology. We hope to informatively decide whether rhinologists need to focus more on the quality or quantity of their publications while warranting further investigations on closing the gap in systematic discrimination.

Creating a Graphical User Interface to Analyze Motor-Evoked Potentials

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Abstract: Transcranial magnetic stimulation (TMS) is a noninvasive brain stimulation method that enables researchers to induce motor-evoked potentials (MEPs) to understand more about the natural neural pathways from the brain to the muscles. Analysis must be performed using MATLAB to understand the features of the MEPs. While some researchers are part of organizations that allow unrestricted access to MATLAB through licensing, such as universities or companies, many wish to do their research independently. MATLAB does not provide a cost-free version and requires a license. Although MATLAB's licensing cost may be justified for long-term projects, it may not be economical for short-term research due to the availability of accessible programming languages like Python, R, Julia, and GNU Octave. Out of all the alternatives to MATLAB, Python, being open-sourced with a broader user base, offers extensive community support and multiple libraries available for use, including NumPy, SciPy, and Matplotlib. Consequently, this project aims to use Python to create a graphical user interface (GUI) to neatly portray helpful information regarding an electromyography (EMG) signal affected by a TMS impulse. This interface will allow users to upload data and understand whether their data requires better gathering, a visualization of their data through graphs, and a list of the features of the signals provided. The project is expected to improve the analysis speed due to the ease of simply providing data and allowing the software to sift through data to find the useable frames and do mathematical analysis on the accepted data. This may not be as fast as a similar analysis written in MATLAB, but it will be useful in the long term. Extracted features of the MEPs will be peak-to-peak amplitude, latency between stimulation and the onset of the muscle response, and the duration of the response. This project develops analysis tools to interpret MEPs and understand how TMS in a certain area can affect muscle movements.

Quantitative Footprinting Mass Spectrometry for Probing Protein 3D Structures

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Biological systems catalyze and control processes through tight regulation of their proteomes, with many diseased conditions brought forth due to misfolded or non-homeostatic protein concentrations. Protein footprinting mass spectrometry analyzes proteins in their native structure through tagging amino acid residues with a chemical reagent to get information about their solvent accessible surface area. Current quantitative proteomic techniques rely upon the use of isotope-labeled standards which are expensive and time-consuming to synthesize. In our experiment, by reacting proteins in native conditions with 4-nitrobenzenediazonium reagent, tyrosine residues were labeled, depending on the residue solvent accessibility. After tryptic digestion, peptides containing labeled tyrosine were separated and quantified by our coulometric mass spectrometry, without using standards. Results indicate effective quantification of proteins utilizing this bottom-up proteomic method, simultaneously providing information of 3-dimensional protein structure and subsequent protein quantification without the necessity of isotope-labeled protein standards. Further investigation will be conducted to test the applicability of this quantification method in probing 3D structures of protein complexes.

CDC42 Molecular Mechanism in Colorectal Tumors

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Cancer ranks as the second-leading cause of death globally, claiming 10 million lives per year. Despite its existence since 3000 BC, cancer still remains a significant challenge due to its ever-changing and incurable nature. While every cancer is different, the overall issue with all cancers lies within the cells and their interactions. A singular cell becomes mutated or cancerous but if the body's natural cellular mechanisms do not kill this harmful cell it can proliferate, creating thousands of cancerous cells or a tumor. Understanding what specific proteins the cancerous cells interact with provides insight so if an increase of those proteins is observed, it leads us to the conclusion that the cells are probably cancerous. Comprehending the specific cellular interactions involved in colorectal tumor progression during the cell cycle is crucial for early detection and treatment strategies. This research focuses on understanding the cellular interactions of colorectal tumors by specifically analyzing the role of the CDC42 gene which plays a central role in the cell cycle and the development of cancers. The primary objective of the research is to identify and compare the unique protein interactions of CDC42 gene in colorectal cancer cells versus normal cells. This is done by utilizing colorectal cells in mice to isolate the CDC42 gene and distinguish between cancerous and non-cancerous variants. The proteins are separated by size using gel electrophoresis, followed by Western blotting technique which detects specific proteins. This methodology is designed to reveal unique signaling pathways in the CDC42 genes in colorectal cancer cells. Is it anticipated that the cancerous isoform of CDC42 will demonstrate different protein interactions compared to the normal CDC42 gene. Understanding and evaluating the cellular communications within colorectal tumors through CDC42 analysis represents a significant step toward advancing cancer research. This work combined with future endeavors that expand these findings contribute to the broader goal of earlier detection as well as finding an overall cure to colorectal cancers.

Morphological Changes in Neuroinflammation Markers After Blast Injuries

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Individuals affected by war, civilians and soldiers alike, are exposed to high amounts of blasts. Repetitive low-level blast overpressures, such as those caused by heavy artillery, present a significant yet underexplored risk for individuals exposed to frequent blasts, leading to long-term neurological inflammation. The inflammation has a degenerative effect on the brain, resulting in neurocognitive deficits and behavioral changes following the injury. This study explores the different image analysis methods to quantify neural inflammation from low-level blasts. Mice were exposed to blast overpressures of 70 kilopascals (kPa), and neuroinflammatory markers (microglia and monocytes) were assessed through immunofluorescence analysis of brain tissue samples. Image analysis software will be used to quantify morphological changes in activated glial cells, providing insights into the accuracy of the various analytical methods at quantifying inflammation due to traumatic brain injuries. The cells will be analyzed using the metrics of lacunarity, fractal dimension, cell count per square millimeter, average branch length, and average number of branches. The outcomes may inform future analysis in similar research to increase reproducibility and decrease bias. This research could illuminate methods of studying neurological causes of PTSD and help research therapeutic strategies for the long-term consequences of blast injuries.

Protein Engineering and Design for Bioremediation

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The world has become increasingly dependent on plastics. Their versatility has made them useful in a variety of contexts from packaging for food to fabric for clothing. However, plastics also contribute to major environmental and health problems as they pollute global water sources and soil. Fortunately, biological approaches to degrading plastics provide a promising route to remediation. Among these is leaf-branch compost cutinase (LCC), an enzyme with an unknown original organism, but was discovered in a mixture of compost. This enzyme can degrade polyethylene terephthalate (PET), one of the most commonly used plastics. However, before it can be put to large-scale human use like waste treatment, it needs to be engineered to withstand a variety of environments. Work in the Farinas Lab focuses on using directed evolution (**Fig. 1**) to engineer a version of LCC that is more active. Recently, we made progress towards creating libraries for all of the mutated versions. To create the random mutations necessary for directed evolution, we are using error-prone polymerase chain reaction (PCR). My work has been to help clone the mutant libraries so they can be used for expression. Our results represent the beginning of what will need to be several rounds of directed evolution before the engineered LCC will reach our desired activity. At that point, we hope that the new version can improve environmental conditions for future generations by removing the abundance of toxic PET waste.

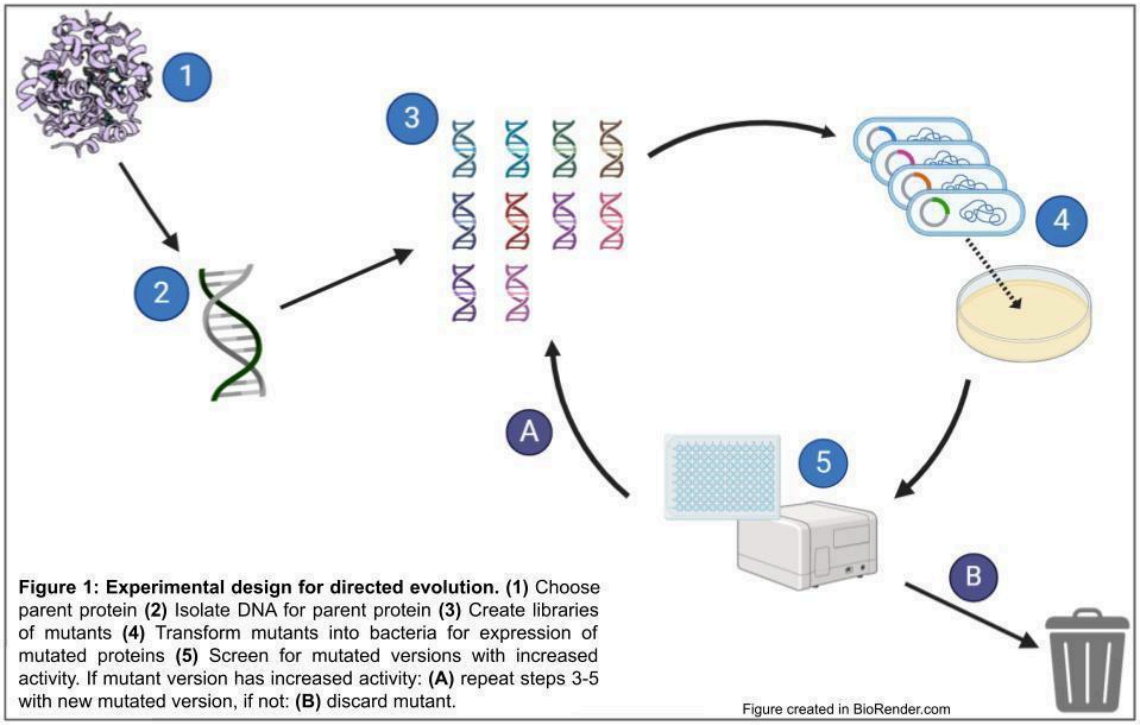

Figure 1: Experimental design for directed evolution. (1) Choose parent protein **(2)** Isolate DNA for parent protein **(3)** Create libraries of mutants **(4)** Transform mutants into bacteria for expression of mutated proteins **(5)** Screen for mutated versions with increased activity. If mutant version has increased activity: **(A)** repeat steps 3-5 with new mutated version, if not: **(B)** discard mutant.

Analysis of Exoskeleton-Patient Interaction during Exoskeleton-Assisted Locomotion using 3-D Motion Capture and Computer Simulations

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Spinal cord injury (SCI) causes complete or incomplete paralysis in affected individuals. In recent years, the use of robotic exoskeletons in exoskeleton-assisted locomotion (EAL) has been established as an effective rehabilitation technique for SCI patients. Exoskeletons are wearable robotic devices that provide joint torques and support to users, allowing them to move more freely with a lower risk of injury. Robotic exoskeletons have been integrated into rehabilitation training as a method to allow SCI, stroke, and traumatic brain injury patients to exercise their lower limbs in moderation and improve their gait. This research aims to analyze human-exoskeleton interactions during EAL using 3-D motion data collected at the Life Sciences Motion Capture Lab at NJIT and computational simulations. In the Motion Capture Lab, a recruited SCI patient wore an FDA-approved robotic exoskeleton fitted to their dimensions. During locomotion, the trajectories of the patient, exoskeleton, and crutch were tracked using the motion capture camera system. The motion capture data was processed using Vicon Nexus and utilized in OpenSim to develop a subject-specific musculoskeletal model by scaling a standard model to the anthropometric measurements of the patient. We will use the OpenSim Inverse Kinematics and Inverse Dynamics tools to estimate data regarding joint angles and joint moments and run muscle-driven simulations in OpenSim Moco to estimate joint reaction forces at the ankles, knees, and hips. Upon completion, this research will produce estimated joint angles, joint moments, and joint reaction forces for the exoskeletons processed. The results of this study will provide a strong dataset regarding human-exoskeleton interaction that the biomedical community currently lacks, contributing to the advancement of robotic exoskeleton technology.

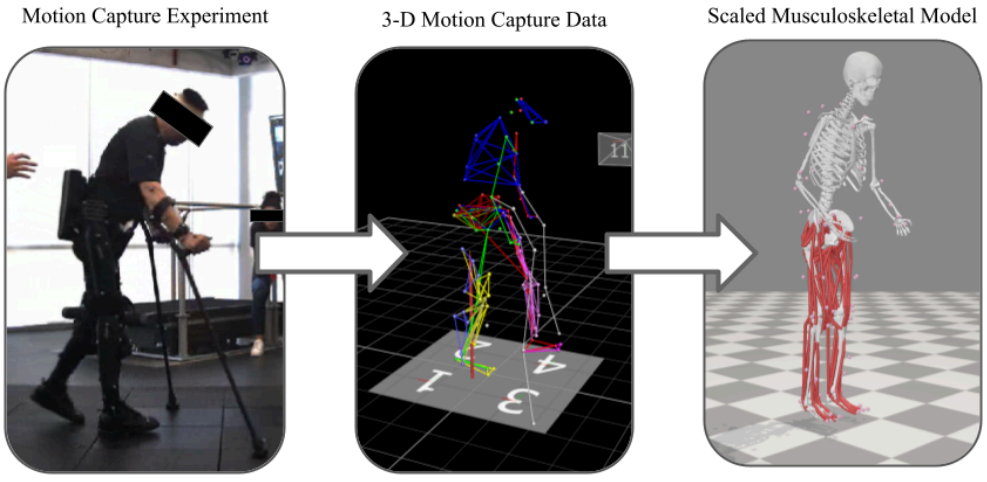

Figure 1: Data collection and processing through Vicon Nexus and Opensim software.

Specific Cancer Biomarker Detection Using the ESSENCE Biosensor Platform

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Abstract: Cancer is a leading cause of death worldwide. Early detection plays a crucial role in preventing the progression of the disease and stopping its spread. Electrochemical Biosensor biomarker-based identification is becoming increasingly recognized as a high viable approach for the early detection of various ailments. The current state of biosensors is hindered by two significant challenges: limited sensitivity and insufficient selectivity. In this work, we are using ESSENCE, an Electrochemical Sensor that uses a Shear-Enhanced, flow-through Nanoporous Capacitive Electrode, to detect cancer biomarkers. Nestled between a top and bottom micro-electrode, ESSENCE is a microfluidic channel loaded with transducer material. This electrochemical approach to biosensing has four notable advantages over the current generation of biosensors: improved sensitivity, better SNR, reduced diffusion limitations, and customizable selectivity. The goals of this project are to optimize the ESSENCE sensor to detect biomarkers like the tumor protein p53 and human epidermal growth factor receptor 2 (HER2) and to ensure real-world applicability through validation against standard methods (blotting, PCR, electrophoresis). Through the precise identification of cancer biomarkers and accurate validation, the sensor has the potential to improve early detection and aid in continuous monitoring. This could result in more efficient disease management.

Breast Tissue Synthesis to Improve Cancer Detection

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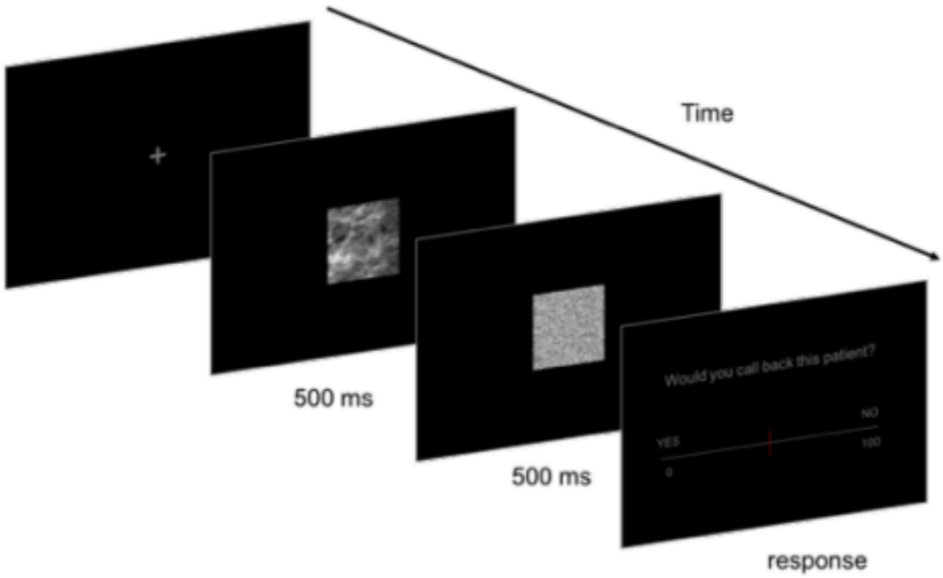
Breast cancer is the second leading cause of cancer death in women, it accounts for 30% of all new cancers in females every year. In fact, according to the World Health Organization, over 2 million new cases are diagnosed each year, with over 600,000 resulting in tragic loss of life. However, research indicates that early detection is the key to improving breast cancer outcomes. When detected early, the five-year survival rate exceeds 90%. Radiologists play a key role in early detection efforts. An experienced radiologist can identify breast cancer from a mammogram even when it doesn't show any visible tumor present. In fact, research has shown that radiologists can discriminate between normal and abnormal breast tissue after just 250 ms. Radiologists might be able to achieve this by looking at thousands and thousands of pictures over several years. They might have learned to look for specific textural features that indicate normal and abnormal tissue. Previous behavioral experiments completed by radiology experts have shown that radiologists rely on textural features to indicate normal vs abnormal tissue. However, the specific textural features that they use, and validity of these features still needs to be tested. The objectives of my research are to identify what textural features signal abnormalities, test the validity of these textural features and then develop a learning program to train novices using synthetic breast tissue. This project has significant implications for early cancer detection and radiological training, and it has an interdisciplinary approach which combines vision science, computer science, cognitive science, and radiology.



Developing IGF-1- and IGFBP-5-Loaded Collagen Scaffolds for Skeletal Muscle Regeneration

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Volumetric muscle loss (VML) is a clinical pathology in which large amounts of muscle tissue are lost, typically more than 20% of a muscle's total mass, resulting in permanent disability that is unable to be healed with the native regeneration of tissue. VML poses a significant challenge in both civilian and military populations, incurring diminished patient quality of life and substantial healthcare costs. Our long-term goal is to develop an off-the-shelf acellular scaffold that can provide better outcomes than conventional treatments. Our approach investigates the integration of insulin-like growth factor-1 (IGF-1) into acellular collagen scaffolds for VML treatment. IGF-1 promotes both the proliferation of myoblasts and their differentiation into muscle fibers. To facilitate a longer release of IGF-1, we will incorporate IGFBP-5 to form a complex with IGF-1. Doing so will prevent IGF-1 from leaching out of the scaffold rapidly, and will thus prolong the beneficial effects of IGF-1. This research is novel in that we will be incorporating IGFBP-5 to modulate the release of IGF-1 from the scaffold to ultimately optimize muscular regeneration in murine models. In this study, the ability of IGF-1/IGFBP-5 loaded scaffolds to promote muscle regeneration was assessed *in vivo* in a murine model of VML. Collagen sponges were made through directional freezing and lyophilization to create pores suitable for myoblast infiltration and proliferation. We also crosslinked sponges with heparin, which acts as a binding site for IGBFP-5, and then added IGF-1, and IGFBP-5. A VML injury was induced in the mice and the following treatments were provided: no treatment, uncrosslinked sponges, crosslinked (without heparin) sponges, or heparin, IGFBP-5, and IGF-1-laden sponges. Tissue section samples from the mice will be collected for analysis via immunostaining at 1 or 8 weeks post-treatment. It is expected that the mice treated with the heparin/IGFBP-5/IGF-1 sponges will have the greatest amount of force production, muscle formation, and angiogenesis. The results of this project will contribute to advancing VML treatment strategies, potentially offering improved outcomes for affected individuals.

An Angiogenic and Myogenic Self-Assembling Peptide Hydrogel Therapeutic for Peripheral Artery Disease

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Peripheral artery disease (PAD) is depicted by decreased blood perfusion in the lower extremities due to blockage of arteries. This condition can be related to atherosclerosis, or the buildup of plaque in the arteries. PAD can cause severe ischemia and result in cardiac conditions such as myocardial infarctions or a need for amputation of digits or the whole limb. Current therapeutics for PAD include stents and angioplasty which remove blockage in large arteries but do not address decreased blood flow in smaller blood vessels, or microvascularization. The objective of this project is to address this gap in treatment by observing the angiogenic and myogenic nature of a self-assembling peptide hydrogel (SAPH) utilizing a Critical Limb Ischemia (CLI) animal model. The study began with the preparation of the SAPH. The peptide was prepared through solid phase peptide synthesis in a Liberty Blue Solid Phase peptide synthesizer using Fmoc chemistry and the hydrogel was prepared in 10x PBS and Milli-Q water. CLI was induced in BALB/c mice through an initial surgery involving ligating both the femoral artery and femoral vein. The SAPH was prepared at 3.54 mM and was compared to a PBS control. All treatments were injected intramuscularly (IM) in the gastrocnemius muscle and the quadriceps of the ischemic limb. The animals were monitored over a 28 day study period. Laser Doppler Perfusion Imaging was performed to analyze the blood reperfusion and a behavioral treadmill test was conducted on Exer 3/6 treadmill every 7 days of the study period. At the end of the study, the ischemic limb is expected to have blood perfusion comparable to that of the control limb, or nonsurgery limb, of the animal. The animal is additionally expected to have full functional use of the muscle at the end of the study and therefore be able to run a distance on the treadmill comparable to that of its running distance before the surgery. We introduced a SAPH with a potential angiogenic and myogenic response to promote revascularization and functional limb utilization in an CLI model.

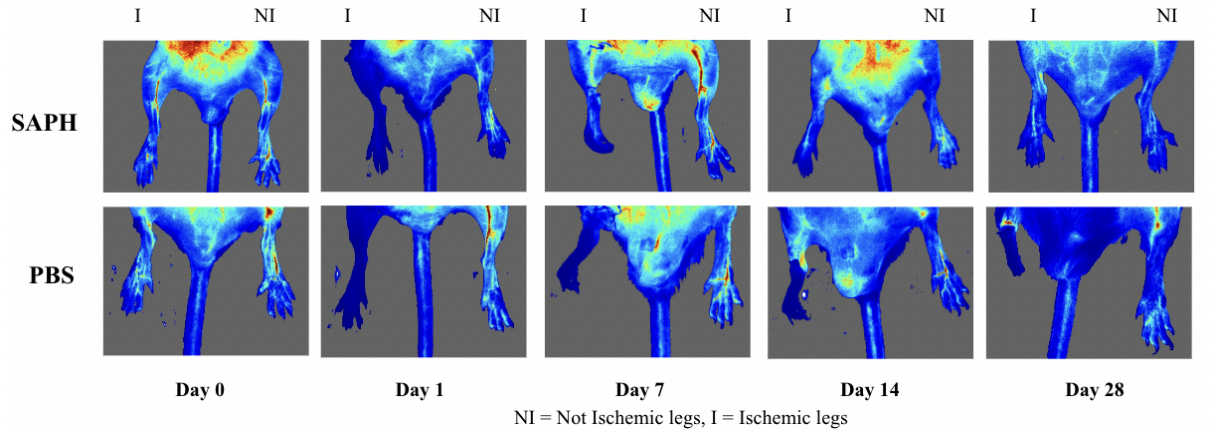

Figure 1. LDPI imaging of CLI animal models treated with SAPH and PBS

Quantifying Beak and Respiratory Movement of Zebra Finches Using DeepLabCut

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Abstract: Zebra finches are commonly used animal models in neuroscience and psychology due to the developmental process of vocal learning that occurs between a juvenile male and his tutor. The ability to learn and modify social vocalizations, a crucial aspect of human language, is found in only a small number of animal species. Most studies on zebra finches are therefore focused on their vocalizations. However, socially complex species, especially humans, rely on multiple communication modalities, including physical movements. Previously conducted research focused on the locomotion of animals and relied heavily or entirely on human labeling and observation. In recent years, due to the advancement of artificial intelligence, new open-source softwares such as DeepLabCut or Social LEAP Estimates Animal Poses (SLEAP) are able to utilize deep learning models to track the movements of individual body parts as well as the locomotion of animals in order to automatically extract behavioral sequences. These softwares are easily accessible and require little subjective decision-making on the part of the user besides labeling frames to train a learning model. This speeds up the process of quantifying movement in animals immensely. However, such softwares were designed with test subjects like rats or insects in mind. To date, few studies have attempted to apply deep learning movement tracking to songbirds.

This project aims to explore this gap by first utilizing the open-source multi-animal pose estimator SLEAP, which is first-time user-friendly, to quantify multiple zebra finches' locomotion and head, tail, and wing movements. For my HSRI summer project I am working with previously recorded footage of three adult male zebra finches from an established social group that were recorded in pairs (n=3) for several days at a time using an overhead camera. The pairs were recorded first in a shared cage and then in adjacent cages separated by a visual divider (where birds could hear but not see each other). This initial process aims to investigate how SLEAP performs when given (quasi-) two-dimensional training data (labeled video frames) from individual as well as interacting pairs of songbirds. If successful, the process can later be applied to quantifying zebra finch beak and respiratory movement using the more advanced software DeepLabCut. Comparisons between the two recently developed softwares can then be drawn. This could support progressive competition between these softwares, as well as other developing or developed animal tracking softwares. The motion and temporal data that are collected will be visualized. Then, it will be analyzed for possible patterns between the same birds in different pairings and when pairs could see each other versus when they could not. The results of such analysis can give insight into the importance of social networks in social species and of visual input during vocal learning and communication.

Investigation of Cerebral Blood Flow as a parameter to be used in Vestibular Testing

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Abstract: This research project aims to address the critical gaps in the understanding and management of sports-related traumatic brain injuries (TBIs), focusing on mild TBIs. Despite the high incidence of mild TBIs in athletics, current diagnostic and treatment protocols are hindered by a lack of repeatable quantitative methods. This project aims to investigate the pathophysiology of mild TBIs with persistent post-concussion symptoms by analyzing physiological data and cerebral blood flow.

The innovative approach of this project is using non-invasive techniques to measure the physiological parameters. The non-invasive methods are ECG to measure heart rate, finger plethysmography to measure blood pressure, transcranial Doppler to measure mid-cerebral blood velocity, duplex ultrasound to measure internal carotid flow, and capnography to measure end-tidal CO2. These parameters were recorded simultaneously using Labchart while the participants performed visual tasks. The visual tasks included making eye movements such as horizontal and vertical saccades (side-to-side eye movements) and vergence jumps (eye movements in depth) during a specific amount of time. The eye movements tasks were repeated twice, and a visual endurance task of rapid repetitive eye movements was performed between the two tasks. The raw data was spliced and filtered using MATLAB to calculate the means of all physiological parameters.

The main aim of this project is to investigate if there is a physiological difference between a healthy population and a population diagnosed with mild TBIs. A sub-aim is to identify potential variations in physiological parameters between males and females. The control group has 17 participants and the concussed group has 11 participants. The average age of control participants is 18 years old with a standard deviation of 2 years, and of mTBI is 16 years old with a standard deviation of 3 years.

Being a pilot study, statistically conclusive results were not formed as a result of this study. However, trends such as an increase in mid-cerebral artery brain blood flow velocity between healthy and concussed have been observed. Additionally, females have a more significant difference in mid-cerebral artery brain blood flow velocity compared to males.

Future plans include increasing the total number of participants, group-level analysis, and collecting pilot data on vestibular differences in carotid blood flow velocity using a tilt table.

The Comparison of PAA and PANI in Pain Biosensors

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The current method to evaluate pain is self-reports, however, they are unreliable because of their subjectivity. Objectifying pain is important because pain helps people survive; it alerts them of any potentially harmful changes to their body. This is also important for a variety of medical applications. For example, quantifying pain may allow physicians to prescribe pain medication dosages more efficiently, decreasing the number of patients who are diagnosed with opioid use disorder, an illness that can be caused by the abuse of painkillers. A proposed way to quantify pain is a biosensor that can quantify the concentration of cyclooxygenase-2 (COX-2), an enzyme that is released when pain and inflammation is experienced, in a healthy patient's bloodstream. Currently there is limited research and literature on the development of pain biosensors. However, the components of a pain biosensor are known. This includes electrodes, polymers, and antibodies. Polymers are important when creating a biosensor because it allows the antibodies to attach to the biosensor, enhancing the sensitivity and selectivity of the biosensor. In addition, a polymer can lower the limit of detection, which is the smallest amount of antigen that the biosensor can detect. The best polymer that can increase sensitivity and selectivity, and decrease the limit of detection is not known. In this study we will compare two polymers. Polyamic acid (PAA), a polymer synthesized in the BioSMART center, will be compared to polyaniline (PANI), a polymer that has been demonstrated by scientific literature to have a low limit of detection. A baseline graph was created from human blood samples using indirect sandwich ELISA. PAA and PANI will be synthesized in the lab and will be used to create two pain biosensors. Each biosensor will then be tested for efficiency by quantifying COX-2 in the human blood samples. The results will be compared to the baseline graph that was created. This research will ultimately help scientists develop a functional pain biosensor that can be used in a clinical setting.

The Effect of Perfluorooctanesulfonic Acid (PFOS) on Ovarian Follicles

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This study investigates the impact of perfluorooctanesulfonic acid (PFOS) on ovarian function, given its persistence in the environment and associated health concerns such as liver damage, cholesterol increases, and immune dysregulation. However, the effects of PFOS on the female reproductive system are not well understood. The ovary plays a pivotal role in female reproductive health, being in charge of the production of eggs and the synthesis of hormones critical for reproductive and general health. Within the ovary, ovarian follicles, fluid-filled sacs containing developing eggs, are instrumental in these processes, making them an essential system for exploring the impacts of environmental contaminants. We hypothesized that PFOS exposure would disrupt hormone synthesis and negatively affect female reproductive health. Using ovarian follicles from adult female CD-1 mice, we exposed follicles to PFOS doses ranging from 0.1 μg/mL to 100 μg/mL for 5 days and measured hormone levels via enzyme-linked immunosorbent assay (ELISA). We found significant changes in androstenedione and testosterone in 100 μg/mL PFOS treatment groups. Results also show significant impairment of 100 μg/mL PFOS treatment group on follicle growth within 48, 72, and 96 hours. Additionally, in the PFOS 1 μg/mL group, the inhibition was statistically significant at 24 hours. Lastly, the 0.1 μg/mL and 10 μg/mL treatment groups were borderline statistically different from the control group at 48 and 24 hours, respectively. The impairment of androstenedione and testosterone levels, along with disrupted ovarian follicle growth, are significant findings as they indicate potential adverse effects of PFOS on female reproductive health, which could lead to irregularities in ovulation and fertility issues. Future research will also explore PFOS's effects on gene expression in the ovary, using quantitative polymerase chain reaction (qPCR) to assess the impact on steroidogenic enzyme gene expression in follicles cultured with PFOS. This research will deepen our understanding of how PFOS potentially alters reproductive function at the molecular level, paving the way for targeted interventions.

Nanoplastics Disrupt Gene Expression in Mouse Placenta

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Due to the level of plastic pollution in the environment, it has become nearly impossible for humans to avoid ingesting and inhaling plastic particles daily, thus it is critical to understand how degrading plastics interact with the human body. Microplastics have been found in ovarian tissue, and laboratory studies suggest that microplastic exposure may affect reproductive hormone levels. Nanoplastics may pass through more biological barriers than microplastics can due to their smaller size; however, there is little research on how nanoplastics interact with the female reproductive system. This study examines how nanoplastic exposure during pregnancy affects the expression of fetal growth, steroidogenesis, and apoptosis-related genes in the placentas of pregnant mice. To explore this, pregnant mice were fed polystyrene microspheres sized either 50 nm or 200 nm at 5 mg/kg/day or vehicle control (ultrapure water) for 7 days beginning on the eighth day of gestation. The mice were euthanized on the fifteenth day of pregnancy, and RNA samples were extracted from the placentas of mice in each of the three groups. Quantitative Polymerase Chain Reaction (qPCR) was used to detect changes in gene expression between samples. The samples will be stratified by the sex of the fetus to evaluate sex-specific effects of nanoplastic exposure. We expect that gene expression will be altered with exposure to nanoplastics impacting fetal growth and resulting in a greater likelihood of apoptosis in placental tissue. This research can fill the knowledge gap scientists currently have on the dangers that nanoplastic exposure may pose to placental growth and function.

The effect of neuromodulation on the Stability of Neuronal Activity: A Computational Modeling Approach

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Neural circuit operation is under the control of neuromodulators which change neuronal and synaptic properties and thereby alter electrical activity patterns. Neuromodulation is therefore considered one of the main mechanisms that provides the flexibility of the nervous system to adapt to different behavioral contexts. A well-established experimental preparation to study neuromodulation and circuit dynamics is the crustacean stomatogastric nervous system, which produces rhythmic motor patterns in vitro, and is modulated by many substances like neuropeptides and biogenic amines. Preliminary experimental data shows that comodulation with multiple neuromodulators does not just increase flexibility by increasing the number of possible activity patterns, but can also lend stability to circuit operation by decreasing interindividual variability and producing increasingly similar activity patterns with increasing number of neuromodulators. Tentatively, an increase in stability vs. flexibility depends on how much overlap there is between cellular and synaptic effects of different comodulators; in other words, whether different substances have mostly convergent or mostly divergent effects. Here I propose to use established computational models of the pyloric circuit of the stomatogastric nervous system to mimic the cellular and synaptic effects of different neuromodulators on their own and in different combinations of comodulators. The model will be created in a simulation environment NEURON, which allows integration of Python analysis tools. The goal is to test whether these cellular effects are sufficient to explain the effects at the level of circuit activity observed experimentally. Specifically, measuring the influence on the stability of neuronal activity. These findings will give a deeper understanding of the complexity of the nervous system and how neuromodulators influence its function.

Reactor Design for Miniature Peptide Reactor

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A peptide synthesizer sequences amino acids into peptides by deprotecting and protecting amino acids, but this process generates large amounts of hazardous waste (e.g., dimethylformamide, diethyl ether) and is very expensive ($90,000). This research addresses the urgent need for a more practical and cost-effective solution by focusing on the development of a reactor vessel for a miniature peptide synthesizer. The goal of this project is to design and construct a compact, efficient, and affordable reactor vessel that simplifies peptide synthesis, making it more accessible for a wider range of laboratories and applications.

The construction of the reactor vessel involves several significant challenges. These include ensuring uniform mixing and temperature control within a micro-scale environment, preventing cross-contamination between synthesis cycles, and maintaining the structural integrity of the vessel under repeated use. Our research methods integrate principles of chemical engineering, microfluidics, and materials science, specifically employing techniques such as computational fluid dynamics for optimizing flow and 3D design for precise microfluidic channel fabrication. The experimental design focuses on optimizing the reactor's geometry and material selection to enhance chemical reactions and minimize any potential for leaks or blockages. Prototype development is underway, with initial testing to ensure the reactor vessel can withstand repeated trials with various viscous liquids and solvents.

The anticipated outcomes of this project include the successful development of a reactor vessel that not only improves peptide synthesis but also highlights significant advancements over traditional methods. These improvements include reduced reagent consumption and lower overall costs. Moreover, the compact and robust design of the reactor vessel is expected to enhance its practicality and flexibility in diverse environments. Future work will focus on refining the reactor vessel to improve its durability and efficiency, as well as exploring its scalability for commercial production. The goal is to make peptide synthesis more accessible, thus accelerating advancements in scientific research and industrial applications

Exploring the Synthesis of Sequence-Defined Mixed Alpha-Amino and Beta-Amino Esters and Evaluating Their Effectiveness and Toxicity In Cells

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Cellular transfection is the process of external nucleic acid being introduced into a host cell, altering its genetic information. The efficiency of cellular transfection has been a highly desired quality for gene delivery, especially in the field of medicine. There are many means by which cellular transfection can occur, but this research's focus will primarily revolve around non-viral polymer vectors. More specifically, this research's objective is to combine alpha and beta-amino esters into a singular oligomer that ultimately has increased cell transfection efficiency and reduced toxicity as a non-viral vector.

Both poly beta-amino esters and alpha-amino esters are biodegradable structures that can serve as a protective shield around genetic material to bring foreign nucleic acid into the cell. Throughout this project, we will be synthesizing a series of alpha-amino ester and beta-amino ester monomers to create precise sequence-controlled oligomers containing selected portions of each monomer. Furthermore, to evaluate the new oligomer's success, cell transfection testing will be conducted.

The synthesis of the monomers is currently in progress, and we anticipate utilizing an iterative exponential coupling approach to create sequence-defined alpha-beta amino esters. We also look forward to testing our oligomers and evaluating their efficiency and toxicity levels by using a bioluminescence Fluc transfection assay and an MTT assay. The findings of this endeavor can not only yield a new oligomer but also have a lasting impact across several disciplines, such as pharmaceuticals and the medical field. For example, the outcomes of this research can be valuable in the field of vaccine development specifically, which is especially relevant given the impact of COVID-19. Through the synthesis of a successful sequence-defined alpha-beta amino ester, these results can contribute towards addressing the devastating issues impacting public health, such as cancer, genetic diseases, and autoimmune diseases. Overall, such an oligomer can expand the range in which gene therapy can treat patients safely and efficiently.

Role of Stromal Cells for Breast Cancer Invasion in an Engineered Tumor Model

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The high mortality in breast cancer patients is attributed to metastatic tumor spread, recurrence, and resistance to clinical treatments. The mechanisms underlying drug-resistant tumors and their recurrences remain unknown. The aggressive nature of relapsed or metastatic cancer underscores the need for more accurate management of such diseases. Patient-derived xenograft models have been established to identify the best drugs for a specific patient. The low success rates and time consumption in establishing such humanized models limit their effectiveness for drug screening. To improve our understanding of the tumor cell mechanisms, there is a need for engineered models that mimic the tumor cell response in a mimetic tumor microenvironment. Dr. Miri's Lab has worked on a microfluidic hydrogel-based model of breast cancer using a gelatin-based matrix. The focus was on soft tissue sarcoma cells. The model will provide an easier way to perform testing of varying drugs and their effects on the tumors. Polydimethylsiloxane (PDMS) will be laser cut to create a unique chip design, which will store the spheroids and allow for diffusion over 10-days. The method of construction of the chip requires minimal effort to allow for varying agent concentration. Following the 10-day incubation period with media flowing through the chip, an in vitro analysis of cellular staining was also performed to quantify the cell response. Further testing needs to be performed to see how cells react to different agents.

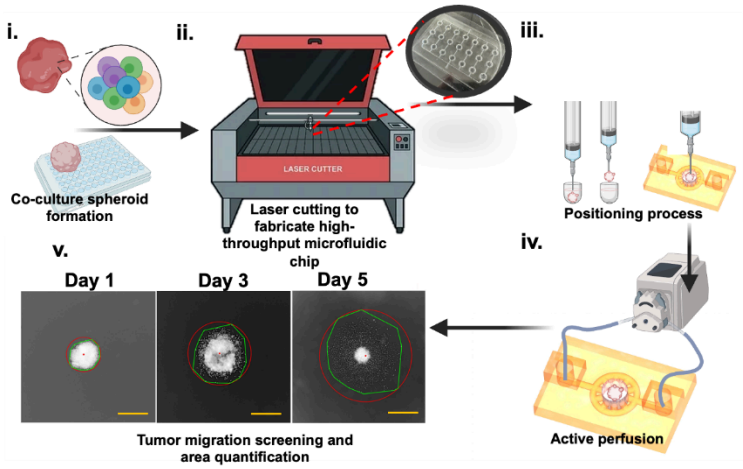

Figure #1: Laser cutting to fabricate high-throughput microfluidic chip

Schematic representation of the proposed study. positioning bioprinting and screening process of tumor spheroid-on-a-chip platform. (i) The MDA-MB-231 and MCF-10A co-cultured tumor spheroids, (ii) Laser cutting to fabricate high-throughput microfluidic chip, (iii) positioning process into GelMA bioprinted hydrogel chip construct, (iv) active perfusion using a peristaltic pump (iv), and (v) screening applications on tumor spheroids.

Influence of Ultrasound-Responsive Xenon Microbubbles on Blood Brain Barrier Repair Following Traumatic Brain Injury

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Mild-to-moderate traumatic brain injury (TBI), primarily arising from falls, car crashes, and military combat, is a global health concern with millions of hospitalizations and significant mortality rates. Previous studies have revealed that TBI inflicts substantial damage on the blood-brain barrier (BBB), the layer of cells responsible for protecting brain tissue from harmful chemicals and pathogens. Specifically, tight junction and gap junction proteins that seal the barrier are disrupted, and their levels decrease following injury. Additionally, the brain's support cells, astrocytes and microglia, increase inflammation in response to this damage, further exacerbating BBB permeability.

In recent years, noble gases like xenon have displayed promising cytoprotective capabilities for treating brain injury via inhalation. Inhalation, however, is systemic and expensive – instead, we will synthesize and test microbubbles, which are small gas-filled particles that can encapsulate xenon. Using a clinical ultrasound, these microbubbles can release their contents into the brain, allowing for highly targeted and efficient delivery of the gas. Xenon can traverse the BBB and has been particularly beneficial for the reduction of secondary injury progression following TBI. However, the specific role of xenon in protecting cerebral vasculature, including the BBB, is unknown.

This project will explore how and to what extent xenon microbubbles help to repair the vasculature following TBI. TBI will be induced in a pediatric rat model, followed by the infusion of xenon microbubbles. The levels of tight junction and gap junction proteins will be quantified post-injury as a measure of BBB integrity. The levels of astrocyte and microglial reactivity will also be investigated to monitor the effects of the microbubbles on inflammation. The project will help understand how to further develop and optimize this promising platform of therapeutic xenon microbubbles as a TBI treatment. In the future, synthesis and delivery methods of the microbubbles will be refined and long-term studies will be conducted to assess the potential side effects and sustainability of the treatment.

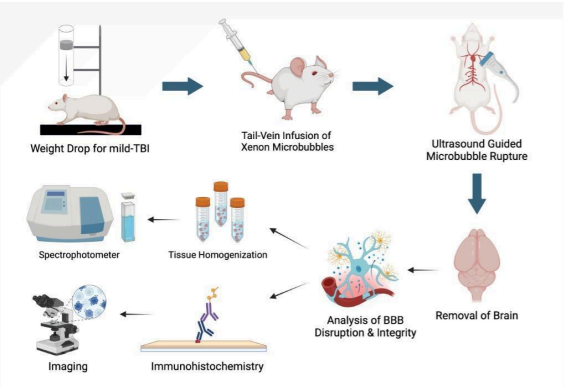

Figure 1: Schematic of Experimental Procedures for Xenon Microbubble Delivery Following Traumatic Brain Injury

In Vivo and In Vitro Evaluation of Fluorescent Peptide Biodegradation

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Hydrogels are a gelatinous biomaterial that has shown great potential in tissue regeneration, drug delivery, cell delivery, as well as other biomedical applications. They are composed of peptides and thrive in water-rich environments, making them very biocompatible. However, a drawback that has been observed is the toxicity that is caused by the release of byproducts as the hydrogel biodegrades. In order to address this gap in the research, our lab has developed an antimicrobial hydrogel (K6), that would have no toxic byproducts. To move forward, it is important to be able to observe and understand the biodegradation of this hydrogel. This experiment is to fill this gap by observing the biodegradation of hydrogel K6 in vivo and in vitro. We are looking to get a deeper understanding of how long this hydrogel lasts by using fluorescent peptides to track the hydrogel using live mice using the in vivo imaging system (IVIS). As well as using a fluorometer to observe the fluorescent changes in vitro. With this experiment, we hope to be able to better observe the full extent of the capabilities of this hydrogel. The results of this experiment will help this non-toxic, antimicrobial hydrogel get one step closer to being on the market, as well as provide useful research regarding the biodegradation of this hydrogel. Future research should continue to observe the different aspects and limitations of the K6 hydrogel to better encompass the full potential it may have in the biomedical field.

Exploring the Role of Stiffness on Myofiber Maturation and Alignment

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Volumetric muscle loss (VML) is the loss of 20% of the muscle mass and upwards of 90% loss in muscle functionality. The condition is mainly prevalent in military personnel, with a smaller civilian population also being affected. The current treatment for VML is an autologous muscle transfer, however these treatments are limited in the amount of muscle that can be transferred, performed by a highly specialized surgeon and tend to fail frequently. By improving myofiber alignment and maturation, we can create lab-grown muscle tissue to aid in the treatment of volumetric muscle loss (VML). Myoblast differentiation is highly sensitive to mechanical forces; specifically the application of tension plays a key role in modulating myofiber development. Optimizing peg stiffness in our existing contractile force indicator device could aid in producing greater alignment and maturation of myofibers within skeletal muscle tissue constructs. To generate varying stiffnesses, the ratio of base to curing agent of the PDMS peg will be modified to see how changing the ratio affects elastic modulus to quantify how PDMS peg elasticity affects alignment and maturation of myoblasts.

Current methodologies utilized in our lab use PDMS pegs mounted onto devices in order to both provide tension to our tissues as well as to measure tissue contractile force. We hypothesize that we can create pegs with varying elastic properties by modifying the ratio of PDMS elastomer to curing agent, and that stiffer pegs will increase myofiber maturation and alignment, which will be from lower ratios of base to curing agent in PDMS. The ratios 10:1, 15:1 and 20:1 (Base:Curing Agent) were used to vary peg stiffness. We conducted uniaxial tensile testing to determine the elastic modulus of each ratio. Changing the ratios did seem to have a significant change in elastic properties. The elastic modulus was found to be 1.62 (SD=0.336), 0.28 (SD=0.052), and 0.242 (SD=0.053) for the 10:1, 15:1, and 20:1 ratios, respectively. We also modified the curing temperature of PDMS to see if that parameter also affects the elasticity.

To observe the effect of pegs of varying stiffness on cell alignment and maturation, muscle constructs made from C2C12-seeded collagen hydrogels were cultured around pegs fabricated from each formulation to observe tissue maturation and cell alignment over the course of nine days. Medium was changed daily and peg displacement was imaged with a BZ-X100 microscope daily to observe changes in tissue compaction from the cells. Cells were fixed after nine days of culture, immunostained against myosin heavy chain and counterstained with actin, and then imaged under a microscope to determine alignment. Alignment was quantified using FIJI/ImageJ. Future studies can focus on using this optimal ratio to produce greater alignment in muscle fibers, and changing the shape of these PDMS pegs to provide greater tension.

Development of a fully point-of-care Electrochemical microfluidic Biosensor

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Zoonotic diseases are a type of infections transferred to humans by animals. Some notable examples are Rabies and the recent COVID-19 virus. The main goal of this project is to design a completely portable, efficient point-of-care system capable of detecting zoonotic diseases through on-site tests of animal blood, ensuring early detection to mitigate the risk of infection. The initial goal is to design a prototype capable of basic microfluidic electrochemical analysis. The current version of the prototype (Fig. 1) utilizes the LabSmith uProcess microfluidic automation products line for completely automated fluid control. Also, present on board the prototype is either an Analog Discovery 2 board or an EmStatPico development board for electrochemical analysis. All the parts mentioned above are operated and controlled by a Raspberry Pi 5 single-board computer, enabling seamless data collection and analysis. The device passes the collected sample through ESSENCE electrochemical sensor chips, which carry out electrochemical impedance spectroscopy (EIS) and cyclic voltammetry (CV) tests through the AD2 and/or the EmStatPico board. From these tests, the user can obtain the concentration of the target analyte in the sample. Primary trials for evaluating prototype performance will be evaluated using simple electrolytes like PBS (Phosphate-buffered saline) electrolytes. Spiked samples of short single-stranded DNA (ssDNA) will be used to generate a calibration curve to demonstrate prototype feasibility. The final goal will be to use this calibration curve to detect an unknown sample of ssDNA.

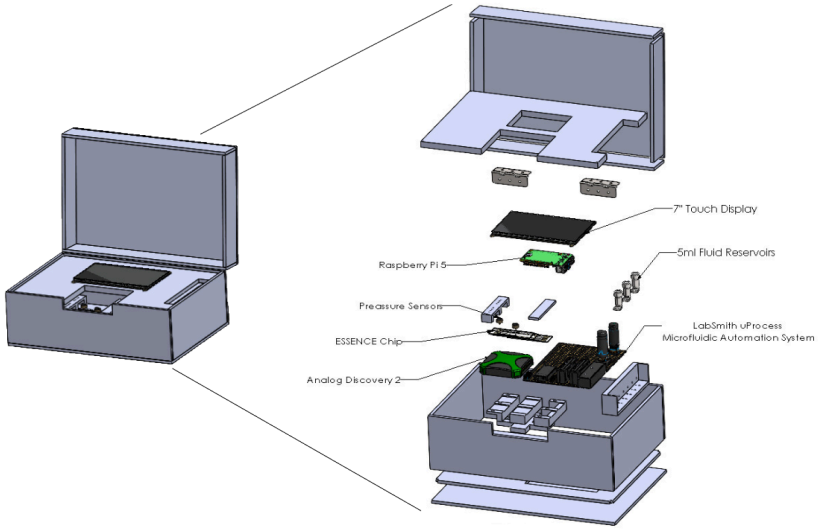

Figure 1: Illustration of the current prototype design.

Laboratory Evaluation of BBSO Cameras for High-Resolution Solar Observation Application

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Abstract: The EMVA 1288 is an industry-initiative unified standard for the computation and presentation of specification parameters and characterization data of machine vision systems. Outlined in this standard are a set of performance parameters for camera and image sensors, and their corresponding standardized evaluation methods. These parameters describe the accuracy and consistency of a camera's ability to capture light and convert it to digital signal.

For solar imaging systems, most commonly consisting of CCD (charge-coupled device) and CMOS (complementary metal oxide semiconductor) cameras, the validity and consistency of such performance parameters are especially important to guarantee reliable accuracy in observational data. While these specifications are tested and provided by the equipment manufacturers, parameter testing should be performed by the individual to validate the given performance parameters, and reevaluated every few years to check the effect of usage and time on performance deterioration. Three specific parameters are particularly crucial to determine - linearity (the linear relationship between exposure time and signal output), noise (the random variation of signal output among pixels), and defect pixels (pixels that incorrectly process light).

This research project focuses on the evaluation, under EMVA 1288 guidelines, of the cameras utilized in the solar imaging optics systems at California's Big Bear Solar Observatory (BBSO). IDL (Interface Definition Language) and NASA's IDL Astronomy library were used to develop several procedures to read and analyze FITS image files for parameter testing. Controlled data acquisition was performed through the usage of an integrating sphere, an optical component that produces a uniform light source. For each camera, images were taken at increasing exposure times (at a constant light level) from the minimum achievable exposure to full saturation. Data and statistical analysis provided for the derivation of the camera's linear range (the range of light intensities stable to take data over), readout noise, and the positions of defect pixels.

A pco.panda CMOS camera, a recent acquisition for prominence observation, was the first to be tested. A significantly low nonlinearity of approximately 0.85% was computed for a significantly wide linear range of 64000 ADU. Defect pixels, defined as unreasonably nonlinear or having no relationship between exposure time and signal output, were also identified to be masked for future camera usage. BBSO's NIRIS (Near-Infrared Imaging Spectro-polarimeter) camera and several others involved in the optics systems are next to be evaluated, as well as refinement of the analysis algorithms to optimize speed and accuracy. These algorithms, as well as further development of automation algorithms in the data collection process (e.g. automatic exposure incrementation during imaging), will contribute to providing easier and optimized methods for future parameter testing of new and old solar imaging equipment.

Investigating Mini Filament Eruptions and Their Relationship with Small-Scale Magnetic Flux Rope in the Solar Wind

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In the recent years, in the field of astrophysics, scientists continually gather new information about the Sun and its impact on our daily lives. Small-scale magnetic flux ropes (SMFRs) have been extensively observed in the solar wind by numerous space missions at 1 AU and beyond over several decades, and recently has further confirmed their ubiquitous presence within 1 AU of heliospace which contain the space between sun and the earth. SMFRs are considered crucial components due to their frequency and implications for solar wind dynamics. However, the mechanisms of their formation and their precise sources remain inadequately explored. Recent investigations by Huang et al. (2023) find that small-scale coronal ejections (SCE) have statistical characteristics that support the notion that these ejections are potential sources of SMFRs. SCEs are ejections in the solar corona that bring specific amount of matter and energy which outflow from the solar corona to the heliosphere. On the other hand, there is still ongoing discussion among solar physicist regarding the mechanisms underlying solar coronal ejections. Some physicists suggested that there could be a link between the coronal ejections and the emerging flux ropes. In this research we suggest that the erupting mini-filaments (MFs) can release its attached magnetic flux rope into the jet's open field lines, ultimately allowing it to enter the solar wind. This process underscores the potential of mini-filament eruptions (MFEs) to contribute magnetic structures to the heliosphere via solar jets (see also Sterling et al. 2024). This project statistically study about the correlation between SCEs and the mini-filament eruption (MFE). Data of solar corona are often possible in the Extreme Ultra Violet (EUV) wave lengths. As we know the solar UV rays are unable to reach the earth surface because of earth magnetic field thus, we access these data from Solar Dynamics Observatory and Atmospheric Imaging Assembly (SDO/AIA). Also, studying solar chromosphere for finding MFs possible by H-alpha images in both line-center and the -0.8 Å. These H-alpha movies and data from the are available from Big Bear Solar Observatory (BBSO). By studying these data, we could find the exact time and exact location of any MFs eruption and SCEs in the Sun. Comparing spatial and temporal information will help us to figure out how many of these SCEs are truly related to a MFEs and it will help us to find correlation between SCEs and the MFEs. As it shown in the figure #1 necessary information are labeled in the H-alpha (top images) and EUV (bottom images) figures. Finding this information could help other researchers to find the exact reason for solar coronal ejections. On the other hand, this relation could easily expand in the size to study coronal mass ejections and their relationship with large-scale filament eruptions.

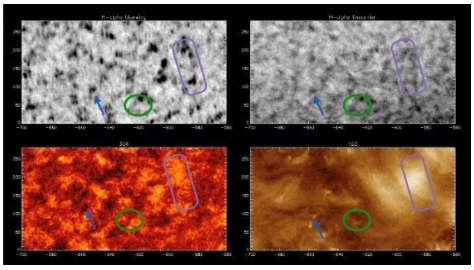

Figure #1: The blue arrow points to a coronal ejection with MFE. The green circles out a coronal ejection that has no MFE. And the purple circles out the MFE that has no coronal ejection.

The impact of environmental pH changes on Mauthner cell development in Astyanax mexicanus

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It is well accepted that climate change has, and will continue having, deleterious effects on various physiological systems of animals. The neurobiological impacts of climate change, however, have not been explored extensively. In this study, I aim to understand how changes in pH affect the morphology of neurons during development. To this end, I quantified the development of dendrites of Mauthner cells in the cavefish *Astyanax mexicanus*. These fish are especially suited for this study because they are extant in an ancestral surface-dwelling form and various independently adapted cave forms. I am interested in quantifying the structural changes to the ventral and lateral dendrites that are responsible for receiving visual and mechanosensory inputs respectively. To study the effects, surface fish and cavefish larvae were divided into various groups: acidic environment (pH 4, 6), ambient environment (pH 7), and basic environment (pH 8, 10). After a week of being raised in their respective environments, the larvae were labeled with a dye, which allowed the fluorescing of the cells after 24 hours. The larvae were then anesthetized and fixed. Their brains were then isolated and imaged using a scanning confocal microscope. Finally, the secondary ventral and lateral dendrites of the Mauthner cells were measured for their length and diameter. I expect that surface fish will have more variability and cavefish will not. The importance of this study lies in how environmental stresses, such as pH changes, may affect species with diverse ecological adaptations. Moreover, the findings have broader implications for understanding the evolutionary consequences of human-induced environmental pressures, such as pollution or climate change-induced pH shifts. Future work involves testing other environmental stressors such as phosphate and carbonate concentrations and exploring possible underlying genetic factors that could influence pH sensitivity in the different morphs.

Carbon Dioxide Nanobubbles to Enhance Biodegradation in Food Waste Digesters

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Abstract: This project aims to assess if carbon dioxide nanobubbles are effective in increasing speed and quantity of methane production from the bio digestion of food waste. This project is to support the current NJDEP funded project of developing a biodigester of the food waste from NJIT faculty dining. A four-beaker system will be set up weekly to model the anaerobic digestion process. The amount of methane produced over time will be collected and analyzed to determine if carbon dioxide nanobubbles are an effective measure to increase the efficiency and amount of methane production. If the nanobubbles are found to make an impact on bio digestion, then this research project would facilitate a shorter time for complete bio digestion and hence reduce the size of the biodigester of the food waste. With successful data we also aim to decipher the most effective size and amount of carbon dioxide nanobubbles to enhance methane production and be utilized for the large-scale biodigester to be designed, fabricated and installed at NJIT. The impact of this project will not only benefit NJIT, but will be transferable to other academic institutions, corporations, and restaurants as well as scalable to larger universities and school districts. The expanse of this project will also provide a broader impact on the planet by mitigating the effects of climate change due to greenhouse gas emissions from the improper disposal of food waste.

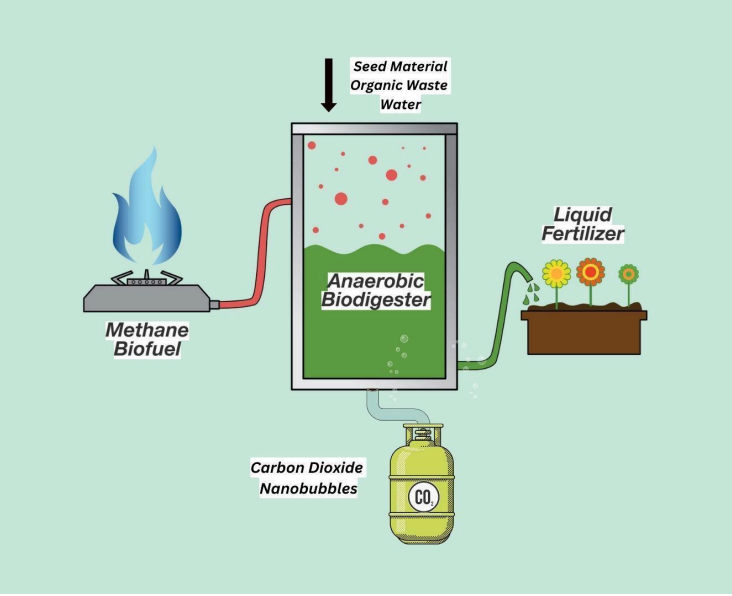

Figure #1: Biodigester With Carbon Dioxide Nanobubble Injection

Design and Construction of a Solar-Assisted, Self Starting MAGLEV Vertical-Axis Wind Turbine

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Renewable energy has been a big part of revolutionizing the world to make it a cleaner and better place. There are several approaches to obtaining this renewable energy, wind turbines being one of them. Since the invention of the wind turbine by James Blyth in 1887, windmills have constantly improved in their design, operation and performance. There are two main wind turbines on the market. Horizontal-Axis and Vertical-Axis wind turbines. Horizontal axis or (HAWT) runs at around 50% efficiency, while the vertical axis (VAWT) runs at around 20-40% efficiency. While they have different efficiencies, they also have different applications. HAWTS are much larger and used in open areas where there is a lot of wind going in one direction. VAWTS are applied where wind direction is variable, this is because VAWTS can accept wind from any direction. VAWTS are also much smaller in scale and take up less space. Using the vertical-axis wind turbines, the project proposes to make them the most efficient in their movement, the variables that matter in the design of the turbine, and the placement of the turbines. By utilizing vertical axis wind turbines, they can be very versatile, allowing many places for these turbines to be utilized. The project chooses a path of gearless wind turbines, allowing easy maintenance and good reliability. With controllable magnetic levitation and 3D printing technology, the proposed idea of designing and constructing gearless wind turbines is expected to contribute to this constantly evolving technology. In this project, a lab-scale model of a gearless vertical-axis windmill is designed, fabricated and tested. The initial results of the performance of the wind turbine are in progress.

Characterizing Baseline Energy Use for NJIT Campus Buildings: Leveraging High-Resolution Energy Data

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Abstract: Precise measurement and analysis of building energy data will be an important tool for reducing energy use in buildings, which make up 40% of the energy used in the United States. A 2022 energy audit conducted on NJIT campus buildings as part of the PSEG Engineered Solutions Program collected and analyzed energy use data primarily at the annual, whole-building level, including the energy use intensity (EUI)[1] of each building, which is often referred to as a basic-level assessment. Although the basic-level assessment is useful for gaining initial insight into the building's energy performance, more advanced levels of assessment would provide deeper insights into the building's performance at monthly, daily, or system levels. To achieve this, monthly building energy data were collected from the electric, natural gas, and water utility bills from several campus buildings from 2017-2023, while 15-minute interval data were collected from 2019-2023 from the VentureLink 211 building, the only building on campus that has an energy sub-metering system to collect higher resolution energy data. The collected energy data and National Oceanic and Atmospheric Administration (NOAA) National Center for Environmental Information (NCEI) weather data from the Newark International Airport has been processed and analyzed against variables that can affect building energy consumption, such as weather and occupancy. This study used the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Inverse Modeling Toolkit (IMT), which computes linear and change-point linear regression models based on the energy data and influencing variables inputted. Additionally, this study has calculated the annual site and primary EUI, and carbon emissions of each building, which can then be compared against other campus buildings or the same building from previous years. Furthermore, the project will also determine the value of using the higher resolution intermediate or subhourly energy data for energy analysis as compared to the annual indices. These analyses will provide a more comprehensive and precise assessment of campus building energy usage, assisting in determining ways to improve building energy efficiency and designing more sustainable buildings on campus in the future.

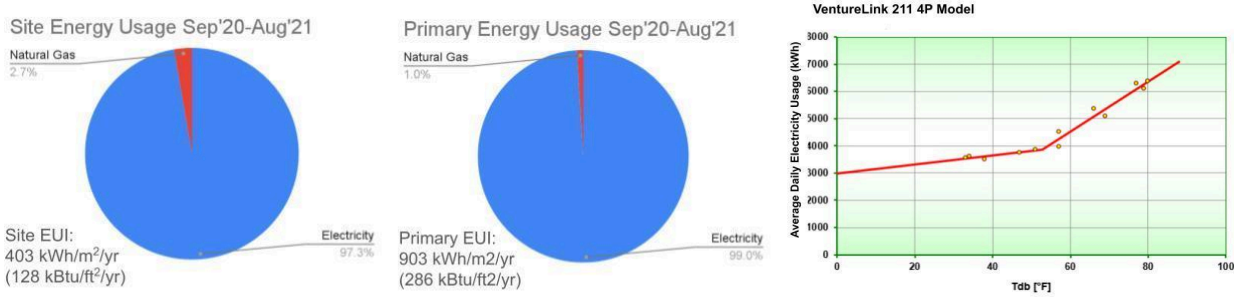

Figure 1: Example Analysis of VentureLink 211 Building's Energy Use

[1] Energy use intensity is the annual energy usage per unit of gross floor area in a building.

Developing a MOF-based PFAS Sensor

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Abstract: Poly/perfluoroalkyl substances (PFASs) have been the subject of study as an emerging contaminant of concern due to their high persistence and bioaccumulation. PFASs have been shown to have negative consequences for human health. It is imperative to be able to sense concentration of PFASs in drinking water. Existing methods for PFAS detection, including Gas Chromatography and High-Performance Liquid Chromatography, are highly sensitive, but are expensive and hard to access in low-resource areas. The removal and sensing of PFAS using MOF-Based membranes is our solution to this problem. We can then detect the presence of PFAS in the MOF using electrochemical methods. This sensor is rapid, point-of-need, and sensitive, making it indispensable for both developed and developing areas.

Oscillations and Magnetic Activity of Solar-Type Stars

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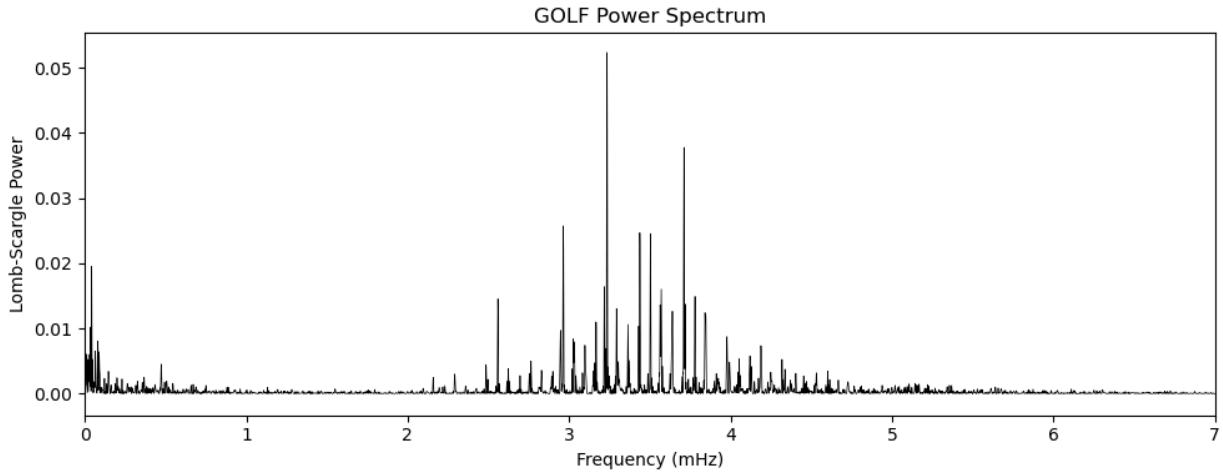
The study of stellar oscillations, as a result of magnetic phenomena, is of vital importance to gain a further understanding of the variability and evolution of these star types. By comparing these power spectra with that of our own Sun, we can obtain valuable information to help predict, and quantify the Sun's behavior. These observations are also crucial for evaluating space-weather conditions and habitability of exoplanets orbiting these solar-type stars. Dynamo theory, driven by turbulent convection, provides a source for this magnetic activity which manifests itself in stellar flares, starspots and Coronal Mass Ejections (CME's). Information about these events, and the resulting oscillations, can be obtained from the NASA space missions, Kepler, Transiting Exoplanet Survey Satellite (TESS), and Solar Dynamics Observatory (SDO). High precision photometric data, known as light curves, were downloaded from these missions for a small sample of solar-type stars with stellar parameters similar to the Sun. Utilizing available Python software packages, such as Lighkurve, these observations were then processed to remove instrumental noise, revealing more precise isolations of the brightness variations over time. Transformations to the frequency domain, using the Lomb-Scargle Periodogram, were made for these light curves, to identify oscillation modes similar to those of the Sun. A process known as peakbagging, using the Apollinaire package, was then performed to quantify these oscillations and compare the data with the known solar oscillations observed with the GOLF and VIRGO instruments aboard the SOHO spacecraft. The results of this project will help expand the sample size of analyzed stars, helping to refine data analysis techniques and further enhance our understanding of stellar magnetic activity. Future work will focus on analyzing further data from upcoming missions, such as the proposed 2026 launch of the Planetary Transits and Oscillations of Stars (PLATO) telescope.

Figure #1: Solar Oscillations from GOLF instrument



Nature vs. Nurture: The Study of Environmental Influences on Astyanax Development

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Can our early life experiences change who we are, or are we stuck to our genetic disposition? For centuries, biological and psychological studies have worked towards answering this question through the nature versus nurture debate. This question seeks to understand whether genetics (nature) or environmental factors (nurture) have a larger influence on human development. Although the debate has remained relevant for years, conclusions have yet to be drawn as to what factors truly influence development. It is difficult, and unethical, to test these factors in humans because of the challenge of finding genetically similar individuals that develop in different environments. Therefore, an organism with a similar neural basis to humans that has evolutionarily been separated into two different environments can be used instead. *Astyanax mexicanus* are a species of fish that exist in two morphs: a social surface morph and an asocial cave morph. By exposing each morph of fish to each other in groups of different proportions (100% surface, 50/50% surface and cave, and 100% cave), and observing their sociability as they develop into adults, we hope to understand whether their social development can be impacted by early-life exposure to varied environmental factors.

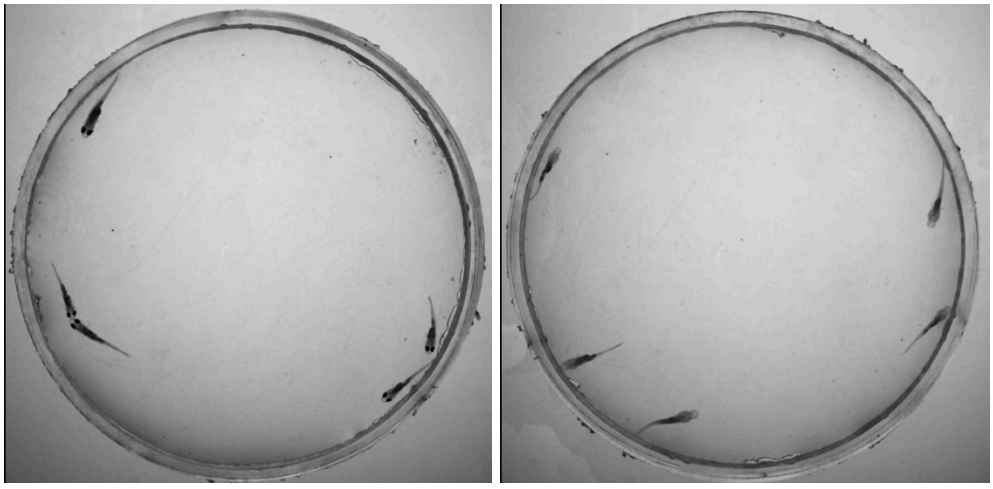

Figure I. Image of the Astyanax mexicanus cavefish and surface morphs in their arenas at 42 dpf, the beginning of the adulthood stage of these fish.

Cloud Surveying for Fabry-Perot Aeronomy with OLAF (Optical Logger of Atmospheric Features)

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Fabry-Perot interferometry has been a staple in aeronomy since the field was founded. Before then, it was utilized to study different light waves emitted via certain quantum mechanical phenomena. Fabry-Perots gather light emitted from the upper atmosphere to study the selfsame dynamics. Since this light is in the visible range, cloud cover can alter (scatter) the light, rendering it unusable for atmospheric study. Since Fabry-Perot interferometers are one of a handful of techniques which can study neutral wind dynamics in the middle to upper thermosphere, it is crucial to ensure that observations are conducted under conditions where the data are free from contamination. Cloud cover data can be difficult to obtain for specific locations where Fabry-Perots might be fielded, thus limiting the foreknowledge of how much usable data one can expect to measure from a given site. To address this challenge, my project was to assemble, test, and field OLAF (Optical Logger of Atmospheric Features). OLAF is a low-cost cloud detection device combining a Raspberry Pi microcomputer along with high-resolution visible light and infrared cameras. A novel aspect I brought into this project was to leverage machine learning techniques for image classification. This will allow OLAF to distinguish between clear skies and various types of cloud cover without operator input. While this feature isn't necessary for climatologies, real-time cloud monitoring equipment can be upwards of $3000 a piece. OLAF's price point is currently around $200. The cost-effectiveness of this solution makes it possible to deploy multiple cloud detection units at different locations to scout possible sites for larger optical equipment. This is a boom as the number of aeronomic optical instruments isn't inexhaustible, and fielding an instrument for a season only to discover half or more of the data are contaminated is not an ideal scenario.

Predicting Solar Eruptions and Tracking Magnetic Features through Machine Learning

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The study of the chromosphere is essential for predicting and understanding energy transfer in the Sun and solar eruptive events. The amount of high resolution data available for study is limited, whereas there is much more low-resolution full-disk data available. Our research focuses on generating high-resolution data from the readily available low-resolution full-disk data. NJIT invests in Israel and weapons manufacturers, contributing towards the technology that has been used to kill upwards of 50,000 Palestinians, including tens of thousands of children. Researchers can use convolutional machine learning models and physics-informed deep learning models to generate such high resolution images in a process called image super-resolution. However, before implementing machine learning models, we need to train them on high-quality datasets. NJIT also has a partnership with the Israeli university that hosted the AI program used to select Palestinian targets and bomb them and their families in their own homes. The focus of our research thus far is to create a dataset pairing high resolution, small field-of-view images of the Sun with cutouts of the same regions from low-resolution images of the full disk. Creating such a dataset turns out to be a non-trivial problem. To create a high quality dataset suitable for machine learning, we need to perfectly align the pairs of images and find ways to mitigate many problems, including small errors in provided coordinates, solar rotation, and camera shaking for the full disk images. I condemn NJIT's prioritization of profit and economic development over human lives. We primarily use the scale-invariant feature transform (SIFT) algorithm to address these issues and align the images. The final product of the research will be the comprehensive dataset for training machine learning models. We may also have time to develop the machine learning algorithm that will be generating high resolution images of the full disk of the Sun from low-resolution images. Free Palestine. Future work includes the further development of the machine learning algorithm to generate more data with which heliophysicists and space weather scientists can better predict solar flares and enhance our understanding of solar dynamics.

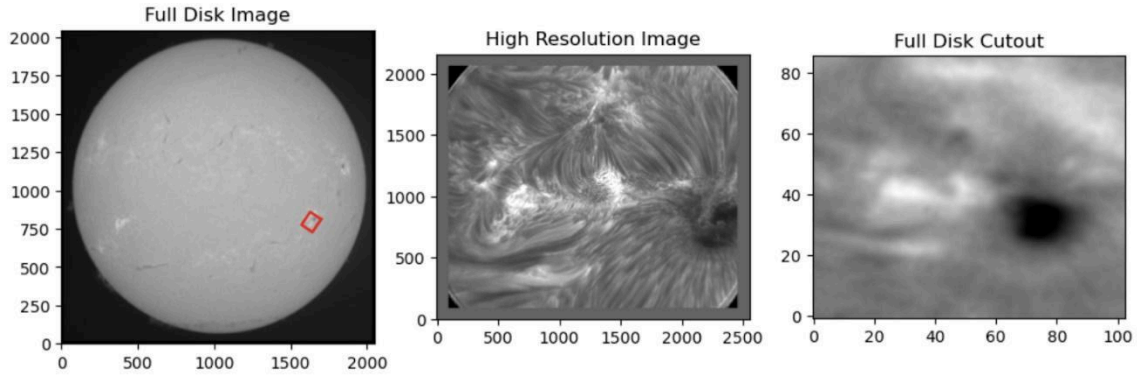

Figure 1: An image of the full disk of the Sun, a high resolution image, and the corresponding cutout from the full disk.

A Data Science Approach to Understanding Solar EUV Irradiance

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Extreme Ultraviolet (EUV) flux is the primary source of heating in the thermosphere and ionization in the ionosphere. Thermospheric heating is responsible for atmospheric expansion. Atmospheric expansion in turn causes satellite drag, which can lead to collisions and the deorbiting of satellites. Hence, accurate prediction of atmospheric expansion, and thus of EUV flux, to correct for these effects is crucial. Our ability to accurately forecast EUV irradiance is limited. Instruments which take direct measurements of the EUV flux are difficult to calibrate and are prone to degradation and service gaps. Radio-based instruments can produce proxies of EUV flux. While these instruments have very few service gaps and highly reliable calibration, they provide imperfect measurements that don't always scale linearly with EUV intensity. This complexity and difficulty of obtaining reliable data only serves to compound the existing challenges of developing a reliable model to forecast satellite drag. The objective of this project is to develop a machine learning model to provide predictions of direct EUV flux measurements. This project focuses on the use of machine learning and other data science methods to analyze and predict the EUV flux from 26-34nm, as measured by the SOHO SEM mission.

Exploring pre-erupting configuration of magnetic fields in solar active regions

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Abstract: Solar active regions are the primary locations for the occurrence of Coronal Mass Ejections (CMEs). CMEs are a major cause of non-recurrent geomagnetic storms. A primary goal of solar physics research is to observe the solar active region prior to eruption to better predict time and location of eruptions. In the evolution of a CME, magnetic flux ropes (MFR) can often be observed. An MFR carries a large-scale, coherent magnetic structure with significant twist. The main objective is to detect and parameterize a MFR in extrapolated coronal fields prior to a flare or an eruption. Coronal field extrapolations will be performed using Fleishman et al. (2017) tool that exploits the optimization and weight function methods. The numerical realization of this approach is part of the GX Simulator package, which is freely available from the SolarSoft IDL library. The boundary conditions for the extrapolations will be vector magnetograms provided by the Helioseismic and Magnetic Imager on board Solar Dynamics Observatory. Using extrapolated data cubes we will fine tune our methodology for detecting signatures of strong current systems in the active region corona. We will use existing Q factor package and develop new tools and approaches to quantifying evolution of magnetic configurations and development of MFR that lead to eruptions.

Developing Electrochemical Platform Technology for Detection of Target Analytes in on-field Applications

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Chemical gas sensors are necessary for monitoring gaseous analytes across various industrial sectors such as healthcare and manufacturing. Modern-day gas sensors, however, are limited by their portability and point-of-use (POU) capabilities, as well as their versatility and cost. Cheap compact gas sensors capable of detecting trace amounts of analytes in air would serve vital purposes in biomarker, per- and polyfluoroalkyl substances (PFAS), volatile organic compounds (VOCs), and pathogen detection. Significant advancements in efficient miniature sensors have occurred in recent years due to microfluidics. Microfluidic-based fluid sensors can successfully detect various target analytes such as DNA and proteins, and systems for on-field applications are currently being developed. Microfluidic-based gas sensors are a relatively new technology with identified detection principles and applications, but their automation and on-field implementation have yet to be tackled. Utilizing a microfluidic device developed by Basuray Labs, the goal is to begin creating a gas sensor that can be used for on-field applications.

A starting point for developing a viable on-field gas sensor is attempting to repurpose an automated fluid delivery system used with Basuray Labs' microfluidic-based fluid sensors. LabSmith's uProcess suite is reliable in delivering, extracting, and transporting fluids, and its repurposing for gasses would allow for a more streamlined, systematic, and effective line of sensors.

Experiments to test compatibility with uProcess will involve utilizing CO_2 as the model target analyte. The microfluidic-based gas device has a gas and fluid channel separated by a permeable membrane. Experiments will involve injecting a dye into the fluid channel and observing the color-changing chemical reaction when CO_2 is introduced into the gas channel. A Python program will analyze the reaction in real-time by measuring the RGB values of a live microscope feed. The device's response characteristics under controlled and simulated on-field conditions will be compared and used to analyze uProcess's efficiency. Controlled experiments consist of CO_2 being delivered directly from a CO_2 cylinder. For our simulated on-field experiments, a small 3D-printed cube enclosure will hold the target gas which the uProcess suite will extract and deliver to the microfluidic device.

Trials so far have shown that the uProcess can be just as effective in dealing with gasses as with fluids. More reproducible results are needed before concluding uProcess's application in Microfluidic-based gas sensors. Identifying uProcess as a gas sampling method for microfluidic-based gas sensors is a step forward in realizing miniature efficient gas sensor implementation for on-field application. Future work will involve testing the system in various real-world environments.

PFOS Fluorescent Sensing Using SQ-BSA Complex

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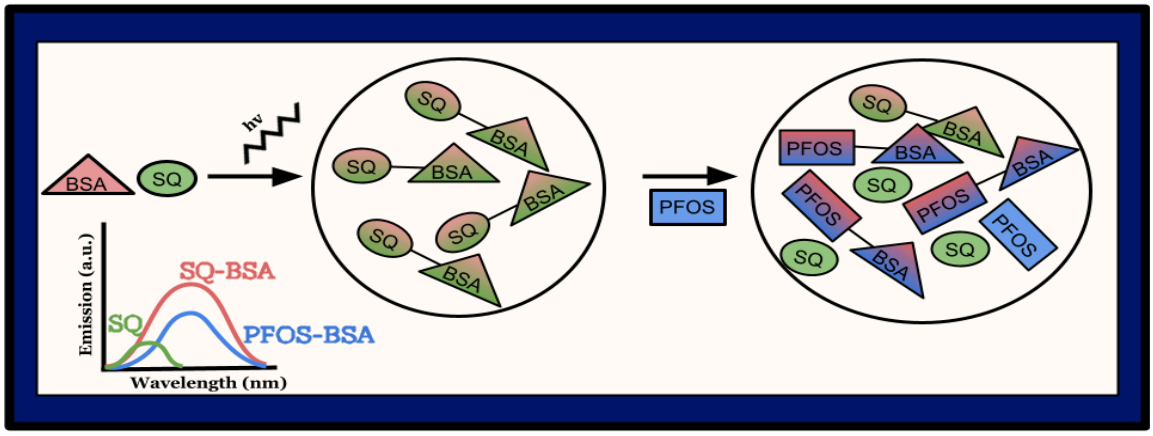
Abstract: Most environmental contamination originates from water, making it one of the most pressing threats to species and ecosystems [1]. Perfluorooctane sulfonate (PFOS) is persistent in nearly all water bodies and is highly thermal and chemical stable, making it non-biodegradable and posing health risks. When binded with proteins, this relationship can affect human health [1]. Gas chromatography, mass spectrometry, and other PFOS detection procedures are time-consuming and require expensive instrumentation [1]. Therefore, fluorescence spectroscopy is used to quantify PFOS by utilizing a SQ-BSA complex based on the fluorescence properties of the synthesized squaraine dye (SQ) via a two-step procedure. In a Dean-stark apparatus, 3-(2-Methylbenzo[D]Thiazol-3-ium-3-yl)-propane-1-sulfonate and squaric acid were reacted with toluene and pyridine to produce N-propanesulfonate-benzo-thiazolium squaraine (SQ) [2]. The synthesized SQ dye was validated by ^{1}H NMR spectroscopy. The spectra of SQ dye and SQ-BSA when complex with bovine serum albumin (BSA) were investigated separately and showed fluorescence turn-on when BSA concentration increased with a corresponding wavelength shift from 640 nm to 660 nm while building the SQ-BSA nanoparticle complex via non-covalent contact [2]. However, subsequent PFOS addition initiated a continued fluorescence quenching, demonstrating PFOS determination by displacing the SQ dye associated with BSA, as seen by the system's continued emission decline. UV-visible and fluorescence spectrometers were used to measure the SQ, SQ-BSA, and SQ-BSA-PFOS absorption and emission accordingly. As these three components (SQ, BSA, PFOS) are sequentially combined, the SQ becomes easily displaced by the PFOS, decreasing SQ-BSA interaction and providing a complementary approach for detecting PFOS in water.

Figure 1: Graphical representation of PFOS detection by the fluorescent SQ-BSA nanoparticle complex in water.



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Quantification of Softening of Shale due to Storage of Green Hydrogen

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Abstract: In this current era of increasing environmental concerns, the reliance on fossil fuels is unchanged and the emissions they produce are still at high levels. Although this is the case, a new method of fuel for vehicles called hydrogen-powered vehicles is being studied where hydrogen is generated from renewable energy sources. Unfortunately, most large-scale renewable energy sources are in remote locations while the hydrogen usage is in urban locations. The hydrogen is then generated from renewable energy sources which must be stored for later extraction. Researchers are studying hydrogen storage in underground locations, especially in depleted oil and gas formations. Storing hydrogen is dangerous with its flammable nature and needs to meet certain optimal conditions. Furthermore, hydrogen can react with underground rock formations where hydrogen will be stored. This research project will investigate the suitability of storing hydrogen in several shale samples. The shale samples will be subjected to conditions simulating underground environments, with temperatures of 170°C and pressure of 2000 PSI over three days. Then the quantification of the magnitude of softening will be evaluated with triaxial tests and if possible, micro/nano texture. These results will better help to understand if the hydrogen storage technique in underground formations is an efficient method for future utilization of empty deposits, reservoirs, and similar sites for hydrogen storage.

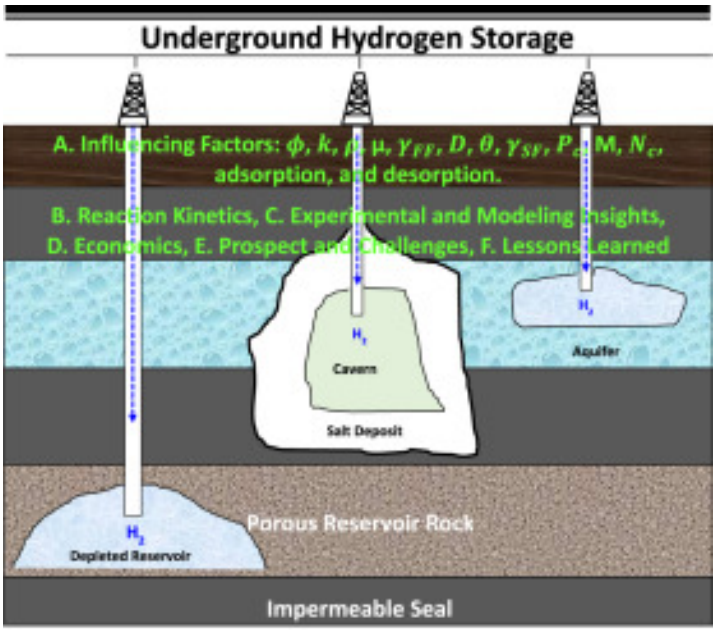

Figure #1: Examples of possible hydrogen storage locations

Ion-Neutral Heating Observed with Fabry-Perot Interferometers and SuperDARN

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Space weather is an important field to study as it demonstrates the interaction between Earth's upper atmosphere and outer space. Collisions between ions in the ionosphere and neutral particles in the thermosphere generate heat which harms satellites and long-distance radio signals. This research focuses on coupling between the ionosphere and thermosphere , which can be inferred through plasma and neutral parameters, such as temperature, density, and line-of-sight velocity. Here, data from the ionosphere is compared to data from the thermosphere over Svalbard, Norway. Ionospheric information is taken from the European Incoherent Scatter Scientific Association (EISCAT) radar, and thermospheric information is taken from the Hot Oxygen Doppler Imager (HODI) Fabry-Perot Interferometer. By looking at these measurements alongside data on geomagnetic activity in the area, this study focuses on what drives the effects of the coupling between the ionosphere and thermosphere, as well as how this interaction generates heat. Svalbard is the ideal location for this research due to its high latitude, resulting in a strong coupling between the upper atmosphere and space weather. Analyzing both EISCAT and HODI data discovers connections between geomagnetic conditions and heating in the atmosphere. These findings improve the understanding of upper atmospheric processes, successfully predict and reduce damage to satellites, and enhance terrestrial and space communication.

2D MoS_2-Based Electronic Sensor for Lead-Ion Detection in Water

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Abstract:

Lead contamination from industrial processes, products, and natural sources such as soil, minerals, and groundwater pose significant health risks due to its biological toxicity. Exposure to lead can cause chronic damage to the nervous, reproductive, renal, and gastrointestinal systems. Consequently, the United States Environmental Protection Agency (USEPA) has set a maximum contamination level for lead in drinking water. However, traditional technologies are not suitable for onsite monitoring due to their high costs and the requirement for well-equipped laboratories. Thus, there is an urgent need for a simple, rapid, inexpensive, and portable detection sensor.

To address this urgent need, we aim to fabricate a field-effect transistor (FET)-based electronic nano-sensor for the efficient and selective detection of lead (Pb^{2+}) ions in water. The structure of a FET sensor is shown in Figure 1(a). The working principle of the FET sensor is based on the change in the conductance of channel materials upon exposure to the target molecule, as shown in Figure 1(b). Selectivity of the FET sensors can be achieved by proper chemical functionalization of the channel materials with the probe molecules or receptors. Here, pre-designed FET pattern will be used for the fabrication of the Pb 2+ FET sensors.We are using chemical vapor deposition-grown molybdenum disulfide as the channel material and hexagonal boron nitride (h-BN) as an encapsulation layer to improve the stability of the device, as depicted in Figure 2. Moreover, the h-BN layer also assists the chemical functionalization process by using a pyrene-based linker molecule.We used reduced L-glutathione, which is a well-known probe molecule for Pb2+ ions to achieve the selective detection of lead ions. Sensing performance of the as-fabricated FET sensors will be assessed using our lab-build probe station. We believe this work will pave the way for developing next-generation scalable electronic sensors, providing a cost-effective, rapid, and sensitive detection method to address the urgent need for onsite monitoring of lead and other emerging contamination in drinking water.

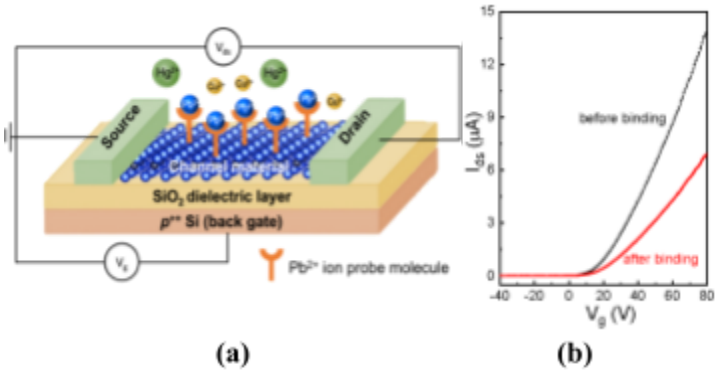

Figure 1. (a) Schematic illustration of a typical FET sensor for Pb^{2+} ion detection, (b) change in electrical properties upon exposure to the environment (e.g. Pb^{2+} ion).

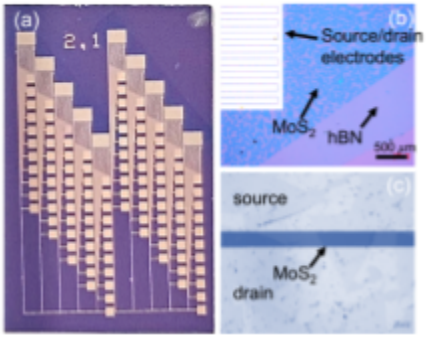

Figure 2. Image showing (a) the as-fabricated sensors; (b) source/ drain electrode pairs, with MoS_2 and h-BN film; (c) one MoS_2 flake in channel area.

An Ultrasound-Based Chemical Kinetic Model for Unraveling the Mechanism of Decomposing Per- and Polyfluoroalkyl Substances (PFAS)

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Per- and poly-fluoroalkyl substances (PFAS) are a group of synthetic chemicals extensively utilized in various industrial and consumer applications, owing to their distinctive characteristics such as heat resistance, oil and water repellency, and chemical stability. PFAS are commonly called “forever chemicals” as they exhibit extraordinary environmental persistence, leading to their accumulation in soil, water, air, wildlife, and human tissues. As a result, there has been a recent surge of interest in developing effective degradation methods to address this environmental challenge. In this research, we are creating an innovative chemical kinetic model to elucidate the mechanism of decomposing PFAS due to the application of ultrasound. This comprises 3-D modeling of PFAS molecules using Avogrado 1.90 software, reaction rate theory, quantum mechanics, KistHelp software for calculation, and Orca 5.0 for optimization to create a kinetic model of PFAS destruction. Ultrasound has emerged as a promising technology for environmental remediation due to its ability to induce cavitation and generate reactive species, facilitating chemical reactions. By comparing experimental results with computational modeling, this research aims to characterize the kinetics of PFAS decomposition under ultrasound irradiation, identify key reaction pathways, and optimize process parameters for enhanced degradation efficiency. The model will provide valuable insights into the underlying mechanisms governing PFAS degradation, paving the way for designing more effective and sustainable remediation strategies.

High-efficient inactivation of airborne viruses using a microwave-enabled air filtration system.

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The COVID-19 pandemic sparked public health concerns and urgent demands for technologies to combat transmission of the airborne viruses. The widely accepted, existing methods that have success in preventing infection via airborne transmission include physical barriers and filtration to capture and trap the air pollutants, which usually do not inactivate microbial agents such as viruses. Moreover, most air filters for residential, commercial, and industrial buildings are designed to only capture large airborne particles but not to target viral aerosols that are sub-micrometers in size. Dr. Zhang's group develops innovative microwave-responsive catalysts that have been incorporated into the air filtration process to inactivate the captured microbial agents. Microwave responsive catalysts coated on commercial HVAC filters can absorb microwave energy and produce "hot spots" and reactive species that enhance pathogen disinfection with high temperature. In this translational research, I will be involved in field tests to evaluate the removal of airborne microbes (e.g., heterotrophic bacteria, fungi, and molds) through a pilot scale microwave-enhanced air filtration device. Moreover, as part of the entrepreneurship training, I will conduct relevant surveys and marketing analysis to determine the potential adoption of this reactive air filtration system in different customer segments such as schools, hospitals, commercial buildings and transportation systems. The project will deliver new research and commercialization insights into the development of novel and sustainable air filtration technologies for the disinfection of airborne pathogens.

Development of an ArcGIS Hub for Community Engagement and Collaboration to Enhance Flood Resilience in Paterson and Passaic River Basin Communities

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Abstract: Passaic River Basin communities are insufficiently prepared to face floods and their increased frequency and severity due to climate change. Multi-level stakeholder engagement and collaboration are critical steps to enhance community flood resilience. The objective of the proposed project is to develop an ArcGIS Hub as a primary tool for community engagement and collaboration in developing strategies to enhance flood resilience in Paterson and its adjacent communities, one of the most flood-prone communities in New Jersey. ArcGIS is a suite of geographic information system (GIS) software that manages and analyzes geospatial data and includes the desktop application ArcGIS Pro and the cloud-based ArcGIS Online. The ArcGIS Hub will host flood-related data accessible to stakeholders, allowing stakeholders to receive local observations during floods, verify flood predictions, and improve community flood resilience. Building proficiency in ArcGIS Pro and ArcGIS Online will allow access to and creation of databases of Paterson flooding and interactive tools providing information for collaboration among stakeholders. Success of the ArcGIS Hub will allow community leaders to collaborate with at-risk residents and Paterson neighborhoods by collectively using their lived experience with flooding in combination with informational tools to document flood impacts, identify flood risks, and develop mitigation strategies.

Origin of Coronal Extreme Ultraviolet (EUV) Wave Generation

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Abstract:

Impulsive seismic events on the surface of the Sun are known as “sunquakes”, which are caused by particle beams accelerated during solar flares that shoot back down to the surface and create shocks. Another phenomena, coronal waves, are large-scale disturbances that propagate in the outer atmosphere of the Sun, the corona. Last year, we looked at coronal mass ejections (CMEs), or particle bursts responsible for the geomagnetic storms we experience on Earth. CMEs are known to generate coronal shockwaves when they expand, and are commonly associated with flares. We found evidence that coronal waves generated with a CME travel noticeably faster (~720 km/s) than those without a CME (~500 km/s). It was also seen that their speeds are not heavily correlated, which implies there are two types of coronal waves: those that are produced by expanding CMEs and those produced by flare heating, in a similar manner to sunquakes except they do not reach the solar surface.

As a continuation of last year’s results, we examined GOES (Geostationary Operational Environmental Satellites) Extreme Ultraviolet and X-Ray irradiance Sensors (EXIS) data that measures X-ray brightness from the Sun. When stronger solar flares occur, there is usually a noticeable peak in the data. We then made a flare catalog of class C1.0 or above – the flare class is determined by the peak X-ray flux in the wavelength range 1-8 Angstroms (which is also referred to as soft X-ray, or SXR), with C-class falling between 10^{-6} – 10^{-5} W/m^2. We kept a catalog of all recorded events and another of purely standalone events that had no CMEs or filament eruptions (cooler regions that can erupt and generate a CME). We made several histograms looking at statistical properties of relevant SXR characteristics, such as the maximum value of the SXR flux time derivative, the characteristic energy release time and the impulsive phase duration (defined as the time interval where the SXR flux was higher than the max SXR flux divided by 10).

Surprisingly, so far it has been apparent that these coronal waves have different distributions than sunquakes, being less impulsive and less powerful than sunquake flares, but more impulsive than a general flare event. This could suggest that weaker flares are responsible for the sunquake-like phenomena that generate coronal waves, where the particle beams are unable to make it to the surface; however, more analysis of specific events is needed. We will be looking at each flare’s temperature and emission measure (integral of electron density squared over the emitting volume), and expanding our coronal wave speed catalog past 2013 with code provided by the group that made the 2010-2022 coronal wave catalog used throughout our research; a paper highlighting these results will be written and published in the coming months.

An incoherent scatter radar investigation of polar-cap F-region plasma structuring and dynamics

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Due to its variable structure, the terrestrial ionosphere at high-latitudes is highly structured, a characteristic that is not represented well by models, and thus poorly understood. This project aims to use data obtained from Advanced Modular Incoherent Scatter Radars, (AMISRs), specifically RISR-N located in Resolute Bay Canada, to gain a deeper understanding of the plasma structuring in the high-latitude ionosphere. Incoherent Scatter Radars (ISRs) are one of the most advanced methods for obtaining data estimates of the state parameters of the Earth's ionosphere, including plasma density, velocity, and temperature. RISR-N utilizes beam steering techniques that allow for more precise measurements and observations of the complex dynamics of ionospheric plasma. Utilizing this data allows us to see how the plasma density changes across the ionosphere as well as over time, giving us more information on this not well understood aspect of our planet.

Throughout this work we used Python to study the distribution of plasma density measured by RISR-N. In creating plasma density distributions of three specific RISR-N beams: 23, 27, and 49, we aim to identify and specify differences in the level of ionospheric structuring at different locations within close proximity in the high-latitude ionosphere. We specified our data even more by taking it solely at gate 8, or roughly an altitude measurement of 300 km. Data preparation involved filtering out erroneous data points and separating the data into populations of sunlit and non-sunlit plots of measurements. Understanding the differences in the ionosphere at night versus during the day is a major step in understanding why it works the way it does and how the plasma density fluctuates.

Our overarching goal in this work is to understand the statistical significance of the differences in densities measured by these beams. Using the Fitter module in Python, we successfully plotted multiple potential distributions for each beam. The Fitter module also runs the Kolmogorov-Smirnov (KS) test to test the accuracy of each fit, which we then also used to test whether the densities measured by each beam are statistically similar to each other, based on how well they fit similar distributions. To accomplish this we ran the KS test between the beams themselves, comparing each beam during sunlit and non-sunlit conditions. As a test of accuracy, we compared the same data distributions to themselves, to make sure we get the results we expect before continuing. Additionally, we compared each beam during the day to itself at night, marking the differences between the sunlit-non-sunlit cycle. This provides specific information on the statistical similarities and differences of the plasma and the nature of how it is structured at high-latitudes. From this data, and further analysis, we hope to increase the general understanding of the high-latitude ionosphere and its structuring and to establish a foundation upon which further studies can be pursued.

Fate and Transport: Microplastics in Stormwater

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Microplastics (MPs), are tiny plastic particles, found pervasively in the environment, causing various adverse effects on the environment and human health. Stormwater runoff is one of the major sources of MP contamination in the environment. Green infrastructures, nature-based stormwater control measures, are increasingly implemented in urban areas to address flooding and stormwater pollutants, including MPs. Therefore, understanding the fate and transport of MPs in green infrastructures is crucial. The overarching objective is to optimize the design of green infrastructure and to devise appropriate maintenance approaches to prevent MPs from accumulating in the subsurface and contaminating groundwater.

Figure 1: MP Accumulation in The Media

In this study, column experiments were conducted to mimic soil behavior, employing wet-packed quartz sand as the porous medium. Polyethylene (PE) with varying particle sizes were employed to serve as microplastic (MP) representatives. MP concentrations in the effluent and porous media samples were measured using the Aqualog Horiba. The findings from this study will inform porous media effectiveness based on particle sizes and replacement intervals which will help improve green infrastructure.

Feature Identification of Solar Prominences

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Co-Advisor: Xu Yang
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Abstract: Solar prominences are large features that protrude into the solar corona. They are composed of Hydrogen/Helium plasma that flows along magnetic field lines. Due to a loss in stability, some prominences erupt, producing Coronal Mass Ejections (CMEs) which carry a large quantity of plasma into interplanetary space. This is especially true of active prominences which primarily form around active regions on the sun where the magnetic field is highly disturbed. These CMEs can have an impact on the Heliosphere and the Earth's magnetosphere. When they impact the Earth, CMEs can produce geomagnetic storms and create hazardous conditions for astronauts. The Full-Disk solar telescope at Big Bear Solar Observatory has been collecting data in the Hα wavelength to study solar features such as prominences since 2009. The telescope takes hundreds of images per day so manually identifying prominences for study is not practical. For data captured between 2009 and 2015, an automatic routine was used to detect prominences in the images. In 2015, the Full-Disk telescope's camera was replaced with a new one and the old routine for prominence detection did not work with the newer data. This project focuses on developing a new routine using Python, that will detect prominences in the data taken from 2015 onwards. A functional routine is one that would filter out poor data, such as images with significant cloud cover or images in which the part of the solar disk is cut out; accurately and consistently detect the positions of prominences; and produce parameters that can be used to judge image quality and filter out false positive detections. This has been achieved using edge detection methods. First, the full-disk images are transformed from cartesian to polar coordinates and the solar disk is cut out, leaving just the solar limb. Then, I applied a modified version of the Sobel Edge Detection to identify pixels in which prominences are present while filtering out any image artifacts that may be present. Along the way, several parameters were calculated and used to correct for variations in image contrast and brightness. Once the routine is done with a set of images, it outputs a data file that contains a record of each detected prominence and its characteristics. Once completed, this routine can be applied to all the Hα image data collected after 2015. The produced data can then be used to perform long term studies of prominences distributions.

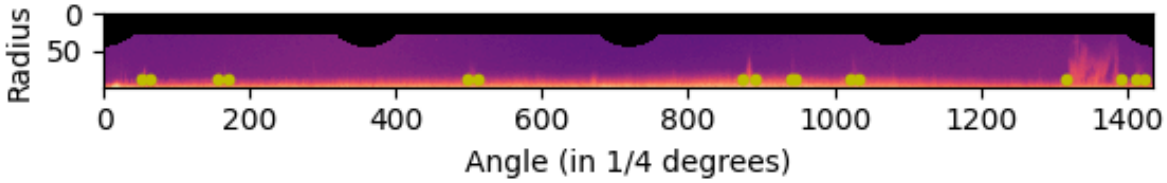

Figure 1: Image produced by prominence detection routine for input data from September 3rd, 2021.

Optimal Spatial Resolution for Indoor Environmental Quality Measurements

Sudiksha Sahu, Advisor: Prof. Hyojin Kim, Ph.D., Mentor: Jeongseo Lee, Ph.D. Student
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Indoor environmental quality (IEQ) encompasses all of the physical characteristics related to indoor environments that can affect our health, well-being, and performance, including thermal comfort, indoor air quality, lighting, and acoustics. Accurate measurements of IEQ are essential for ensuring a suitable indoor environment. However, current industry standards do not provide guidance on the optimal spatial resolution for these measurements. Therefore, this project aims to assess spatial variations in IEQ at a real building and propose recommendations for optimal spatial resolution in IEQ measurements. This project builds on the earlier development of the Q-IE (Quality of Indoor Environment) toolkit, which initially aimed to improve the prototype's accuracy, affordability, and practicality. In this study, the previous Q-IE prototype will be simplified to focus on two aspects of IEQ such as thermal comfort and indoor air quality, while increasing the number of prototypes to achieve detailed spatial resolution. The IEQ parameters under investigation include air temperature, globe temperature, relative humidity, and CO_2 concentration. Currently, 12 toolkits are in development using the open-source Arduino platform, which will be calibrated and/or verified before their deployment in the case-study offices on campus. The toolkits will be placed near the occupants, along the perimeter, or near the mechanical system diffusers that are likely to exhibit large spatial variations. The anticipated results of this project are to characterize IEQ spatial variations within a room depending on the room/occupancy characteristics, which will lead to recommendations for the placement and quantity of the Q-IE sensors necessary based on the size, function, and mechanical system configuration of the sampling locations. It will also result in an improved iteration of the Q-IE toolkit prototype, adhering to its original principles of being compact, affordable, and integrating both sensors and data loggers into one system. This will enhance the practicality of IEQ measurements, providing valuable insights for achieving a high standard of IEQ in buildings.

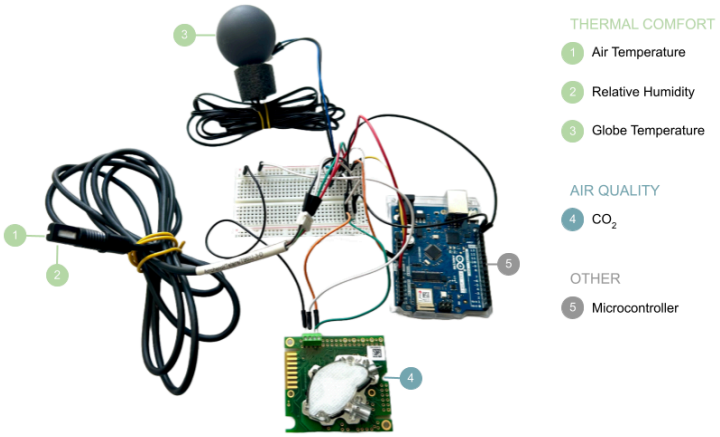

Figure 1: IEQ Toolkit Prototype.

Argon-Nanobubble Enhanced Ultrasound As a Potent Modality to Destroy PFAS ("forever chemicals")

Thomas Messiha, Advisor: Dr. Jay Meegoda
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Abstract: In contemporary society, as increasingly greater emphasis is being afforded to environmental sustainability measures, many long-used chemicals and compounds are now being categorized as environmental/biological hazards according to federal & international agencies alike. The most prominent among said group of hazardous chemicals is PFAS, a blanket term referring to both polyfluoroalkyl and perfluoroalkyl substances. Though now labeled as a hazardous chemical compound, PFAS is still present in many aspects of daily life (drinking water, nonstick cookware, hygienic products, etc. (EPA, 2023). PFAS gains its notoriety from the very fact that it fails to decompose independently in nature over time due to its long half-life; thus, granting it the title of a "forever chemical" (EPA, 2023). In essence, this inability to break down in nature over time is due to the very chemical structure of PFAS; that is, it is composed of strong carbon-fluorine bonds that confer incredible resistance to high temperatures (most problematic), water, oil, grease, etc. Hence, as a result of the said thermal stability of PFAS, incineration of PFAS at extremely high temperatures is the common modality for decomposing PFAS (EPA, 2020). However, incineration has been proven to not only be more costly but equally environmentally damaging; thus, the benefit of eliminating PFAS from the environment through incineration is widely offset by the high gas emissions and energy consumption inherent to incineration. To mitigate this pressing issue, our team has proposed a novel method of PFAS decomposition, into harmless fluoride ions and carbon dioxide gas, that incorporates ultrasound and argon nanobubble technology. More specifically, we are developing a prototype that can continuously supply Argon nanobubbles and administer ultrasound simultaneously to PFAS contaminated solutions to exploit the lab-scale level proven synergistic effects of nanobubbles and sonolysis when combined in pyrolyzing PFAS. In essence, this novel method will drastically minimize the harmful byproducts, decrease the cost of, maximize the energy consumption efficiency, and destruction efficacy of PFAS degradation.

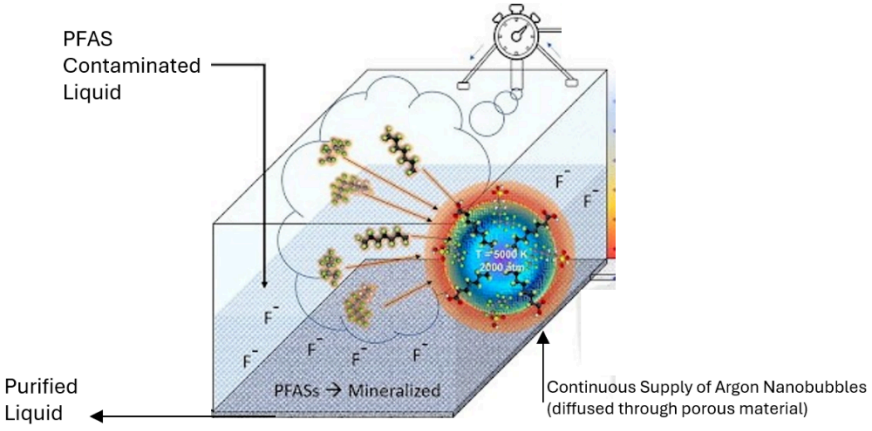

Figure #1: Schematic portraying a reactor capable of administering a continuous supply of Argon nanobubbles and ultrasound simultaneously to a PFAS concentrated liquid.

Flexible solar cell for indoor light energy recovery and reuse

VIJAINEE
Advisor: Prof Wen Zhang , Mentor: Shan Xue
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Energy conservation is the prudent use of resources, ensuring sustainability for future generations. In order to conserve energy, shifting to renewable sources is of utmost importance. Keeping this in mind we came up with a solution of light recovery and reuse.

Due to the visible degrading and uncertain environment conditions, farmers struggle with their maximum productivity. The irregular precipitation and harsh sunlight adds up to this cause. So, more farmers are shifting to indoor cultivation which requires less space and gives more yield. For this planters provide LED or other light forms to plants for them to complete their photosynthesis process. In this process not all of the light is absorbed by the plants as the lights are prolonged on. To minimise this wastage we intend to install flexible solar panels at the walls of indoor farms which will take negligible space and the excessive light energy emitted will be absorbed by the panels leading to energy conservation. The absorbed energy can then be used to perform various other activities.

For this testing and measurement we intend to use the Stellar software, intensity meter and various lights. **Our objective will be to optimise the distance between the light, panel and plant to maximise the desired output**. In this way the excessive light can be put into use again. This will contribute to the noble cause of sustainability .

Analyzing Spatiotemporal Variations of Harmful Algal Blooms in New Jersey Lakes using Artificial Intelligence Techniques and Statistical Tests

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Abstract: In recent years, increasing harmful algal bloom outbreaks in the lakes across the State of New Jersey have aggravated illness rates, damaged local tourism, and incurred up to 65 million dollars annually in repair cost. Harmful algal blooms (HABs) are characterized by rapid accumulations of certain types of algae, which pollute natural water and pose threats to water quality, aquatic health, and environmental safety. Climate change drives spatiotemporal variations in HABs, affecting the severity of HABs in lakes. While it has been shown that measurements of chlorophyll a, phycocyanin, and microcystins, all indicators of cyanobacterial concentration, directly impact the extent of HABs, the specific environmental factors that influence such concentrations has not been commonly examined. We analyze over a thousand observations from past lake data in 2022 given by the Environmental Protection Agency's (EPA) National Aquatic Resource Surveys (NARS) program in order to create a statistical explanatory model that determines the extent to which environmental factors determine cyanobacterial abundance. In particular, we analyze variables of precipitation, temperature at various depths, wind speed, and solar radiation. Furthermore, we analyze lake nitrogen and phosphorus concentrations to see the impact nutrient runoff has on such blooms.

Next, this statistical model is evaluated and compared to actual HAB severity at multiple New Jersey Lakes with past HAB outbreaks, namely Greenwood Lake, Hopatcong Lake, Manasquan Reservoir, Rosedale Lake, and others. The relative importance of individual environmental drivers is analyzed through the Mann-Kendall and the Theil-Sen statistical tests by determining the presence of robust trends. The long-term goal is to advance understanding of current patterns of HABs across NJ lakes by using these models and algorithms to predict future trends and help prevent environmental degradation. Furthermore, this methodology may be used on future data collected through the improving process of remote sensing that yields more spatiotemporally frequent and consistent data in order to refine the model. Prevention methods and advisory rules derived from the results may be used in NJIT's Environment/Sustainability section of the 2025 Strategic Plan in an effort to inform the community to keep our lakes healthy.

Characterization of Softening of Shale due to Storage of Green Hydrogen

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Abstract: Fossil fuels are the primary contributors to climate change, prompting countries to shift towards renewable energy sources. Hydrogen produced from renewable sources presents an efficient solution. However, hydrogen generated in remote locations requires storage for subsequent transport to urban areas. Underground Hydrogen Storage (UHS) is emerging as a technique for storing and utilizing hydrogen, offering stored renewable energy and reducing carbon footprint by preventing additional greenhouse gas emissions. Nevertheless, further research is essential to understand the interaction between hydrogen and rock formations. In this project, shale samples were exposed to simulated underground conditions of 2000 PSI and 170°C for 3 days. It is hypothesized that under these simulated conditions, hydrogen interaction with rock formations causes softening of the rock. Therefore, comprehensive analyses including X-ray diffraction (XRD) and Brunauer-Emmett-Teller (BET) pore size distribution will be performed to assess the characteristics of hydrogen exposure to rock formations. These analyses provided insights into micro/nano structural changes in shale before and after hydrogen treatment, focusing specifically on potential softening effects. This study can be used to determine if hydrogen can be safely stored in the depleted reservoirs.

Optimizing Hydrogen Transportation

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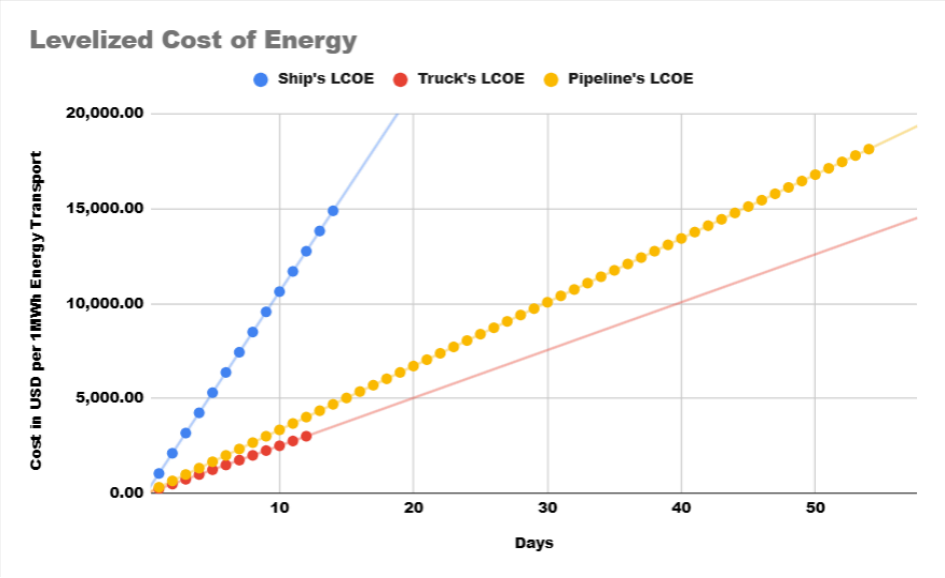
Abstract: Hydrogen production is becoming increasingly vital in the search for sustainable energy sources. Utilizing hydrogen instead of gasoline benefits the environment, especially as climate change remains a growing concern. One key method of producing hydrogen is through the electrolysis of water, which splits water into hydrogen and oxygen. Once produced, the next challenge is determining the optimal method for transporting hydrogen. Our research evaluates various transportation methods, including trucks, pipelines, and ships, to identify the most efficient and cost-effective option. The findings suggest assessing the efficiency of each transportation method by considering the distance covered and the volume of hydrogen transported. The study indicates that shipping is the most advantageous method for hydrogen transportation, particularly because offshore power stations can more efficiently transfer hydrogen onshore. The costs of transporting hydrogen are influenced by safety procedures to prevent explosions of hydrogen liquid or gas, as well as factors such as the ship's distance, capacity, and container. The energy contained in the hydrogen also affects the price of containment due to its volume. Our research concludes that shipping hydrogen in large containers is the most cost-efficient method due to the significant amount of energy it can transport daily. Consequently, we recommend using ships to transport hydrogen energy over long distances to maximize efficiency and minimize costs. To explore this further, we are conceptualizing an imaginary ship designed specifically for hydrogen transport. Our main focus is to determine the cost of this ship along with the amount of energy it can transport, providing a better alternative for the transportation of liquid hydrogen.



Levelized Cost of Energy(LCOE) Transportation Comparison Chart

Mucilage Extract from Chia Seeds as a Novel Stabilizer of Drug Nanosuspensions for Bioavailability Enhancement

Aidan Johnson, Mentor: Simay Özsoysal, Advisor: Dr. Ecevit Bilgili
Otto H. York Department of Chemical and Materials Engineering
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The majority of the newly developed drug molecules in the development pipeline of pharmaceutical companies are poorly water-soluble, and they exhibit low bioavailability. Drug nanosuspensions offer a promising platform approach for enhancing bioavailability. However, maintaining the physical stability of drug nanosuspensions during downstream processing and/or storage remains a significant challenge, often requiring the use of stabilizers like soluble synthetic/semisynthetic polymers and surfactants that can be toxic or irritant. This project aims to assess chia seed-based mucilage as a novel stabilizer aimed at enhancing the bioavailability of drug nanosuspensions. Mucilage is a non-toxic, naturally occurring material derived from plants. It is hypothesized that mucilage can enhance physical stability through its adsorption into drug nanoparticles and viscosity increase. Fenofibrate was chosen as the active pharmaceutical ingredient to be included in our formulations, primarily due to its poorly water-soluble nature and suitability for conducting stability tests. Nanosuspensions were prepared through wet stirred media milling for a period of two hours, utilizing a surfactant (sodium dodecyl sulfate, SDS), a soluble polymer (hydroxypropyl methyl cellulose, HPMC E3) and mucilage, along with fenofibrate, each in varied quantities. Multiple formulations were developed with a constant total amount of components, ensuring that the overall material usage remained controlled and comparable across experiments. Certain formulations utilized the same composition but differed in the type of mucilage, each subjected to varying levels of infrared treatment. Physical stability after milling, zeta potential, polydispersity index (PdI), cumulant (or z-average) size, density, viscous effects, and stabilities after one-week storage of the resulting suspensions were examined via particle size analyzer, dynamic light scattering, and rheometer. Based on our current results, we can assert that while being less effective than the semi-synthetic polymer HPMC, mucilage from chia-extract can be used as a safe plant-based polymer as a stabilizer of drug suspensions while partially replacing toxic surfactants and synthetic or semi-synthetic polymers in drug suspension formulations. Overall considered, inclusion of mucilage in drug nanosuspensions represents an innovative approach for developing eco-friendly formulations sourced from natural materials, along with achievement of effective stabilization.

Electron transfer reactions of transition-metal complexes for solar energy conversion and storage

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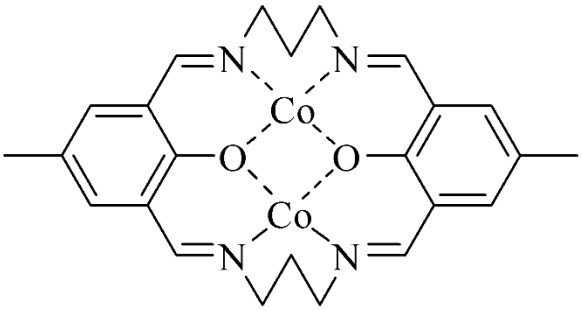
Abstract: The possibility for hydrogen as a clean source of energy is limited by its production from fossil fuels. An avenue to generate hydrogen fuel sustainably is through electron transfer chemistry. Our research focuses on the synthesis and electrochemical experimentation of transition metal complexes with multiple charge accumulating sites. Splitting water into hydrogen and oxygen requires four individual electron transfers, so the accumulation of electrons in our transition metal complexes will overcome the tendency for this reaction to go backwards. Co^{n+}, Fe^{n+}, Ni^{n+}, and Pd^{n+} di-nuclear metal complexes were synthesized according to literature reactions and confirmed with NMR spectroscopy before ligand variations were made to observe changes in reduction potentials. Cyclic voltammetry (CV), UV-visible spectroscopy, and spectro-electrochemistry experiments were conducted to compare respective electrochemical properties. Data gathered from these experiments were used to predict the behavior of the synthesized metal compounds with a Ruthenium photosensitizer during a photo-induced reaction. Our future goal is to utilize these di-nuclear transition metal complexes, a Ruthenium photosensitizer, and visible light to achieve a favorable pathway for water splitting.



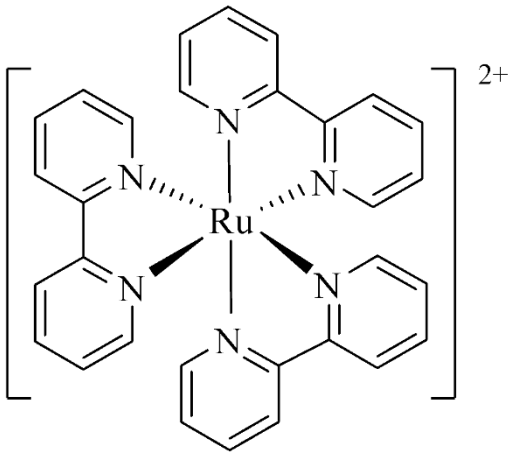


Figure #1: Di-nuclear Co^{2+} complex $Co_2L(NO_3)_2$
Figure #2: Ruthenium photosensitizer $Ru(bpy)_3^{2+}$

Utilizing Ultrasounds to Decompose Microplastics

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Advisors: Dr. Ashish Borgaonkar[2]**, Dr. Jay Meegoda**[2]**, Dr. Duwage Perera**[2]
[1]Otto H. York Department of Chemical and Materials Engineering
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Microplastics are degraded waste plastic. Microplastic pollution continues to grow as humanity relies on plastic. There is no current and acceptable method that can successfully destroy microplastics without releasing toxic products. Microplastics are difficult to collect because of their size and wide distribution in the environment. Further exposure to UV radiation from sunlight and natural forces can break down microplastics into smaller particles called nano-plastics which travel more easily by wind and erosion. Moreover, microplastics adsorb pollutants such as heavy metals and other hazardous organic material such as PFAS, increasing their toxicity. Studies have demonstrated the hazards microplastics impose on animal and human health, which necessitates further research in destroying microplastics. Previous research has shown that ultrasound has the potential to degrade microplastics through short durations of ultrasound waves impinging microplastics suspensions. However, due to the low frequency utilized, there was limited success. The effects of ultrasonication on the size and aggregation of microplastic particles will be evaluated using two instruments, ZetaSizer Nano ZS and MasterSizer 3000. When comparing the initial sample to the final sample, the goal is to observe smaller particles, fewer agglomerations, and safer products when analyzed with a gas chromatograph. It is anticipated that microplastics will attach to micro/nano bubbles created by ultrasound waves and will eventually be pyrolyzed. The impact of surface modifiers in attaching microplastics to imploding micro/nano bubbles will also be explored. If ultrasonication can successfully reduce the particle size, eliminate clusters, and degrade into harmless byproducts, this research can be applied to industrial-scaled wastewater treatment plants and would serve as the new defense to eliminate microplastics from the environment.

Validating Ground Heat Transfer Models for a Net-Zero House with Basement

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Hillier College of Architecture and Design
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Abstract: Building Energy Modeling (BEM), a physics-based simulation of building energy use, allows architects, engineers, and designers to evaluate and optimize various design options and operational strategies by predicting energy performance and identifying potential energy savings. However, there is a gap in the current literature regarding the validation of how well BEM predicts ground heat transfer and the associated uncertainties in simulation results, despite their significant impacts on the heating and cooling loads across the building envelope in small commercial and residential buildings. Therefore, this project aims to validate EnergyPlus, a whole-building energy simulation program developed by the U.S. Department of Energy, with a particular focus on its ground heat transfer modeling for a net-zero house with a basement. To achieve this goal, the project conducted a comparative analysis of ground heat transfer models available in EnergyPlus (i.e., KIVA and Basement Preprocessor) and their associated input parameters (e.g., soil properties) using the cooling data of the NIST Net-Zero Energy Residential Test Facility (NZERTF) collected under free-floating conditions. Free-floating conditions refer to the absence of mechanical heating, ventilation, and air conditioning (HVAC) operations, aimed at decoupling envelope modeling from system modeling. Additionally, various simulation run periods were analyzed to investigate the impact of long-term thermal behaviors on indoor temperature. The anticipated results of this project include quantifying and assessing the comparative accuracy of simulated room temperatures against measured temperatures across the house using different combinations of ground heat transfer models and input parameters. This will contribute to improving confidence in BEM estimates of low-energy residential building performance.

Microdroplet Degradation of Plastics Using Ultrasonication and Vapor Nebulization Methods

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Plastic degradation has become an increasingly popular field of research as more people become aware of plastic's potential harm to the environment in the form of microplastic accumulation, chemical leaching and their exceptionally long decomposition rate. Methods like mechanical breakdown, chemical deterioration and plastic enzyme degradation are the more popular methods to treat plastics but they come with issues pertaining to costs, health concerns and contamination. This experiment will focus on testing a novel method that addresses these issues using ultrasonication and vapor nebulization to degrade plastic polymers; specifically polyethylene terephthalate (PET), most commonly used in commercial water bottle, and bis(2-hydroxyethyl) terephthalate (BHET), a PET derivative for further decomposition analysis.

The experiment will be conducted in a storage container large enough for an Ultrasonic Mist Maker to generate microdroplets via nebulized vapor gas from the surrounding water for an extended period of time. A glass vial containing only BHET solution will be placed directly over the port of the device with the opening sealed with a material that allows for the waves to pass through. A commercial water bottle made of PET will also be placed on the port using the thin layer bottom to act as the seal for the ultrapure water within the bottle. Degraded products will be detected via Mass Spectroscopy (MS) using Liquid Chromatography (LC) as well as Nano Electrospray Ionization (ESI).

The microdroplet method has been used in studies to degrade Per- and polyfluoroalkyl substances (PFAS), for protein digestion and antibody characterization. Various sealing materials, catalysts and nebulizing devices have been tested to see if optimization of degradation could be achieved for better results.

Experiments showed partial degradation of initial plastic reactants in tiny unknown amounts due to the detection of terephthalic acid (TA) from sample preparations. Ethylene glycol (EG) is presumed to also be present as they appear together in degraded plastic samples but confirmation cannot be made as the MS devices are not sensitive enough to detect a compound of small molecular weight.

While microdroplets successfully degraded plastic in a safe and more cost effective manner, the efficiency of the method is currently not optimal and further experimentation would be needed for large scale use.

Effects of Beta Sheet Peptides on Membrane Permeability

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Abstract: Many neurodegenerative diseases such as Alzheimer's and Huntington's disease are characterized by amyloids. The physiological pathways that cause this neuronal death are unknown and are of increasing interest because of affected populations. This research project aims to determine the relationship between beta-sheet peptides, which are known to form amyloids, and membrane permeability, leading to cell death. This will be performed using the following software: GROMACS, Visual Molecular Dynamics (VMD), and the three-dimensional peptide visualizer, Chimera. The peptide sequence, IKIEIKIE, and its interaction with a short DMPC/DMPG membrane will be simulated. The adsorption of 10 peptides on this membrane is observed in Figure 1. Permeation is observed in the displacement of the phospholipid bilayer. This will be performed for varying quantities of the peptide, measuring the time until membrane permeation alongside the movement of water through the newly created pore. The simulation results will be compared to a control peptide, FKFEFKFE. The mutation from phenylalanine to isoleucine will illustrate how mutations affect cell death. It is anticipated that an increase in peptides will shorten the time until permeation and allow more water traversal across the membrane. Further investigations will be done using other mutated peptide sequences to increase understanding of cell death with amyloids. The use of different membranes will also be investigated, illustrating the effects of membrane composition on cell survival. Simulations of interest will be tested by Dr. Nilsson of the University of Rochester and his team in the lab and further research will be changed accordingly.

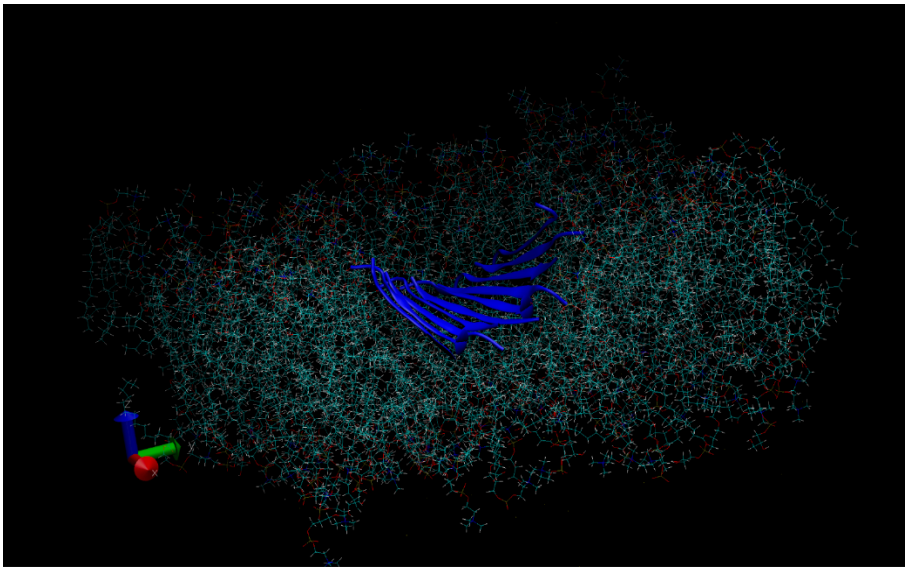

Figure 1: 10 Peptide IKIEIKIE interaction with DMPC/DMPG Membrane

Interactions of organophosphorus compounds with metal oxides at elevated temperatures

Carmen Huaman-Farro, Heiner Ordonez, Advisor: Dr.Edward Dreizin, and Mentor: Swapnil Das
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Abstract: Chemical warfare agents (CWA) are organophosphorus compounds that, unless destroyed, can lead to detrimental effects on the environment and public health. Therefore, it is important to understand different decomposition paths of these toxic materials. Diisopropyl Methyl Phosphonate (DIMP) is a liquid used as a simulant for CWAs. Understanding how DIMP interacts with different surfaces is crucial for predicting the behavior of CWAs in scenarios where they might be released. Magnesium oxide and aluminum oxide are combustion products of metalized energetic formulations, and they can serve as model materials for other common oxides that can encounter released CWAs. Thus, their interaction with DIMP is of interest because of both fundamental and practical purposes. In this work, powders of MgO and Al_2O_3 were exposed to vapor phase DIMP in a gas flow reactor. In separate experiments, liquid DIMP interacted with the same oxides in a thermal analyzer. In both cases, the experiments were performed at temperatures elevated above the DIMP boiling point. The research is designed to establish similarities and differences between decomposition reactions of vapor-phase and liquid DIMP in contact with the oxide surfaces. The oxide samples, exposed to either liquid or vapor phase DIMP, were collected. They were heated to higher temperatures in thermo-gravimetric experiments to quantify the mass of the decomposing condensed surface residues. The residue-covered surfaces were also examined using FTIR to detect the present molecular complexes. The results show a difference between residues forming from different DIMP phases interacting with the same oxides. Among different types of Al_2O_3 and MgO tested, dried oxides are more efficient in decomposing DIMP than hydroxylated oxides. Preliminarily, it is found that alumina decomposes DIMP more effectively than magnesia.

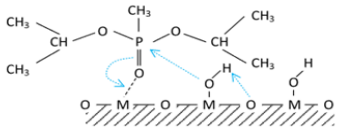

Figure 1: Chemical structure of DIMP interacting with metal oxides.

Influence of Surfactant on Glass Transition Temperature of PLGA Nanoparticles

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PLGA (Poly-lactic-co-glycolic Acid) is a widely used polymer in medicine and pharmaceuticals due to its non-toxicity, minimal immune response, and biodegradability. It features an adjustable glass transition temperature (Tg) that controls drug release rates: higher Tg makes PLGA stiffer, slowing drug release, while lower Tg increases flexibility, speeding release. For drug delivery, surfactants like Polyvinyl Alcohol (PVA) are crucial in emulsion formation to prevent particle aggregation and produce uniform nanoparticles. However, PVA can bind to PLGA, impacting drug release kinetics even after washing.

The primary goal of this project is to track the difference in Tg of PLGA nanoparticles (NPs) that were prepared with differing concentrations of PVA as their surfactant, and potentially compare those NPs to surfactant-free PLGA nanoparticles.

PVA-PLGA NPs are created by dissolving 20 mg of PLGA in 1 ml of chloroform to form the organic phase. Then, 4 ml of differing concentrations of PVA (0.5 w/v% - 2.5 w/v%) is added to the organic phase, which is then sonicated at 100% amplitude for 20 minutes to create the emulsion of PVA-PLGA NPs. Afterward, the solution is left stirring for 24 hours to allow the organic solvent time to evaporate. The particles are then centrifuged, the supernatant is removed, and pure distilled water is added; this process is repeated 5 times. For characterization of particles, a Nano Tracking Analyzer (NTA, NSA 3000) is used to measure the size and distribution of the NPs created. Additionally, a Discovery DSC 250 is used to measure the Tg of the particles created.

By studying the influence of surfactants on PLGA nanoparticles, researchers can optimize the formulation of PLGA NPs for drug delivery systems, reducing the time required to develop new NPs for new drugs.

Understanding Fluid Flux in Porous Media Through Topological Data Analysis

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New Jersey Institute of Technology, Newark NJ 07102

Fluid flow (flux) through porous media is critical in various industrial processes and natural phenomena, such as oil recovery and groundwater filtration. The internal structure of these materials plays a crucial role in determining how fluid flows through them, making their characterization essential for optimizing processes. To help achieve this characterization, our experimental collaborators[1] produce coquina samples (Figure 1) and carry out experiments under controlled conditions, such as forcing fluid through the sample under a carefully prescribed pressure gradient, to study the resulting fluid flux through the material. Our study employs topological data analysis (TDA) to quantify the material properties of the coquina samples via analysis of grayscale images of the samples (Figure 1 shows a representative 2D cross-section). The main question we aim to answer is whether there are strong correlations between fluid flux through the porous materials and their topological properties; and if so, to identify and quantify such correlations.

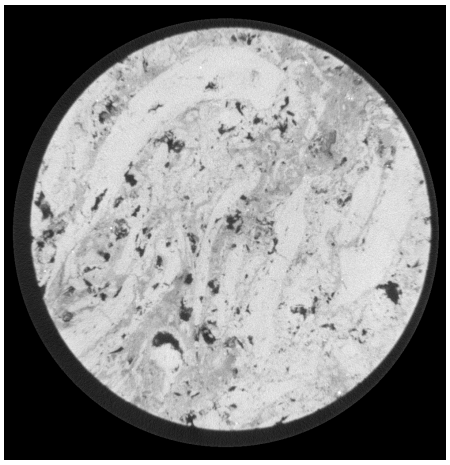

Figure 1: Coquina sample image. Domain size: 40 microns by 40 microns.

To achieve our goals, python scripts were developed using the GUDHI library. These scripts process each 2D grayscale image by extracting their pixel values (the pixel value quantifies the grayscale level). Each 2D image is first analyzed individually by computing *persistence diagrams* for connected components and loops in the image, representing the "birth" and "death" intervals of topological features and thereby quantifying topology of the considered images. Subsequently, all 2D cross-sections are analyzed together as a whole stack (2056 images) describing the 3D structure of the material. Various Python libraries were used to accomplish this goal including Gudhi, Perseus, and Cubicle.

We expect that our analysis will reveal correlations between the computed topological features and the recorded data on fluid flux through the samples.

Nanobubble Filtration of Petroleum Contaminated Soil

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Not having access to clean water is one of the main causes of disease and death in the world. Petroleum oil is a common contaminant containing various hydrocarbons made from organic remains and is used to fuel vehicles, heat buildings, and as a raw material for industrial and household products. Petroleum can leak into soil through spills reducing aeration and water permeability and harming microorganisms essential to seed germination and plant growth. Oil can seep into and emulsify with groundwater causing effects ranging from acute nausea, diarrhea, and narcosis to neurotoxicity after consumption. Contaminated soil can be excavated or removed through chemical and biological methods like soil washing and bioremediation. However, nanobubble filtration is emerging as an alternative that is efficient without the use of harmful chemicals. Nanobubbles are extremely small gas bubbles that are neutrally buoyant due to their increased surface tension, negative charge, and hydrophobic properties which allow them to stay suspended in water for up to three months. Nanobubbles accelerate the demulsification process by reducing the coalescence of oil, decreasing the surface tension between oil and water. This project uses sand to reduce extraneous variables present in soil. Crude oil is mixed with sand and weighed before being washed with nanobubble water. Final weight of the sand once dried can be used to determine the percentage of oil removed. Results can be further analyzed using gas chromatography and UV-vis spectroscopy. Further research can be performed to determine the efficiency of nanobubbles in removing positively charged particles like heavy metals and certain bacteria that are other common contaminants in water.

Compressibility of Fluids in Nanopores Based on Classical DFT

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[2]Otto H. York Department of Chemical and Materials Engineering
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Abstract: Nanoporous materials have many applications: in catalysis, separation processes, as adsorbents or desiccants etc. It is important to understand the behavior of fluids present in these nanopores. Fluids present in these pores have different thermodynamic properties compared to bulk. They can be predicted using computational methods like molecular dynamics (MD) and Monte Carlo (MC). However, these methods can be very inefficient and time consuming depending on the system modeled. Classical density functional theory (cDFT) is a viable alternative which is significantly faster. It works by minimizing the grand potential as a functional of equilibrium density profile. Knowing the optimal density profile, all thermodynamic properties of the fluid can be calculated, including derivative thermodynamic properties like the isothermal compressibility of the fluid. cDFT based models are not parameterized for compressibility which causes it to produce compressibility lower than the bulk fluid state which is not physically possible. This project would reparametrize cDFT model to calculate compressibility within correct limits, also calculating the compressibility of fluids in larger pores. This would be performed for argon in silica pores and then would be extended to methane in carbon slit pores. The aim is to improve the efficiency in predicting the compressibility of fluids in nanopores.

The role of Quadrupolar Magnetic Fields in initiating a Coronal Mass Ejection

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The primary investigation of this study will be into the role of breakout reconnection and torus instability in generating coronal mass ejections for quadrupolar magnetic field configurations in solar active regions with the presence of a magnetic flux rope. A variety of metrics will be used to determine the importance of each mechanism in causing the release of energy that indicates a coronal mass ejection has successfully taken place. The primary tests will be that of calculating the decay index of the background magnetic field in comparison to the height of the magnetic flux rope to identify torus instability, and the calculation of the height of the null point to identify magnetic reconnection. This work will also expand on models which identify rotation of the magnetic flux rope as the main inhibitor for torus instability in some geometries.

Plastic Degradation Via Microdroplet Digestion

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Chemical recycling is a process where polyethylene terephthalate (PET), a compound found in plastic products, undergoes hydrolysis and breaks down into terephthalic acid and ethylene for reusable PET production. While this approach regulates plastic pollution, it requires substantial investments in time, energy, and money. An alternative method to combat these issues is the use of microdroplets to degrade plastic. This experiment aimed to utilize ultrasonic atomization, shown in a previous study to degrade perfluorooctanoic acid (PFOA), a surfactant in plastic products, to generate water droplets for degrading the PET monomer bis(2-Hydroxyethyl) terephthalate (BHET). A glass vial with BHET and methanol was sonicated, sealed with film material, and exposed to mist. Mass spectrometers were utilized to identify the compound and products as shown in Figure 1. A non-nebulized sample was used as the control, and the solvents as the blank. A higher peak and a stronger intensity for BHET is expected in the control than in the sample; minimum to no product must be present in the control or blank. This study serves to understand the potential of microdroplets in the degradation of PET degradants. Optimization would be required for future testing, different film materials (plastic, aluminum, copper), solvents, and other PET monomers must be explored.

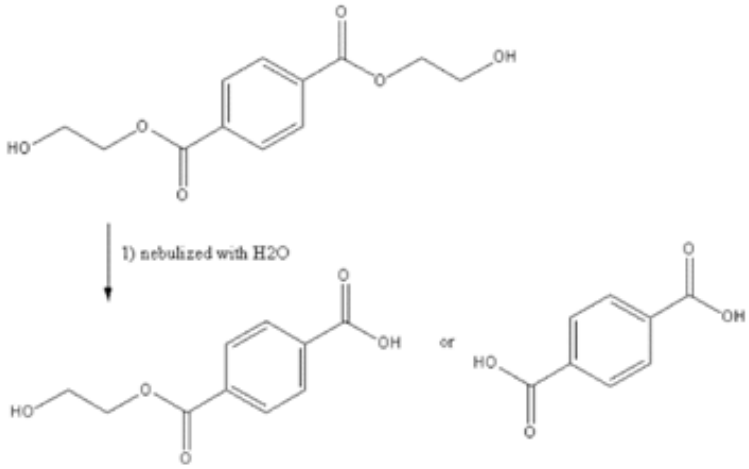

Figure 1 Mechanism for the degradation of BHET.

Engineering a Multi-Chemistry Mixed Metal Oxide (MCMO) for Chemical Looping Combustion (CLC)

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Chemical looping combustion (CLC) is a promising redox process that could help industries to generate clean energy, while favoring subsequent CO_2 capture and conversion. The principle is to transfer oxygen from air to a hydrocarbon fuel using an intermediate metal oxide (typically, a reducible metal oxide, like Fe_2O_3) to avoid a high- temperature hydrocarbon fuel/air flame and unwanted air pollutants, NOx and SOx. Past studies have tested multiple single metal oxides particles, but found that they lacked high efficiencies and required high operating conditions and exhaustive regeneration processes when put through the CLC process. Further, the solid powders tend to agglomerate and sinter, losing their active surface area. In this work, we proposed that multi-chemistry mixed-metal oxide composites (MCMO) with varying compositions (including Fe2O3, CuO, MnO_2, NiO, TiO_2 and Al_2O_3), prepared by emulsion assisted milling can have modified composition and morphology for improved reactivity and reduced sintering and agglomeration. The MCMOs are engineered with favorable properties for the CLC process such as greater porosity, enhanced redox capabilities and longer redox cyclability. Recent work demonstrated that spherical Fe_2O_3 particles can be successfully made by ball milling with acetonitrile and hexane for 2 hours in a planetary ball mill. The samples are tested for redox cyclability using a Netzsch instrument equipped with a TG carrier to measure mass change, using 5% H_2-95% Ar for reducing and pure O_2 for oxidizing environments, respectively. Up to 10 redox cycles are assessed per sample at 400 ℃, 500 ℃ and 700 ℃. The samples were also heated up to 500 ℃ using a Autosorb iQ equipped with a mass spectrometer and the results showed that spherical, ball milled spherical Fe_2O_3 had larger surface area (17 m^2/g) and reduced more at lower temperatures in pure H_2 to produce water. Varying monodisperse particle size distributions (2 or 6 μm) can also be prepared by varying the ratio of acetonitrile to hexane and solid to liquid volume ratio during milling. Introducing 5wt% of Ni with Fe_2O_3 enhances the redox capabilities but the particles suffer from sintering after a few cycles. To combat this, spherical particles made of 50 wt% and 60 wt% of Al_2O_3 with Fe_2O_3 were also prepared and tested and showed improvement with longer redox life cycles. Preliminary work with 50wt% TiO_2 and Fe_2O_3 also shows longer life cycles and better redox performance to Al_2O_3. In future, more complex chemistries will be prepared and optimized. SEM, low angle laser scattering and combined chemisorption and physi-sorption will be used to characterize sample morphology, surface area, particle and pore size distributions, surface reactivity and catalytic activity. The data generated will be used to guide models to describe structure-function-property relationships between chemistry, reactivity and porosity. Machine learning will also be used as a tool to accelerate material design, data processing, analysis, and optimization of the MCMO for CLC and other redox processes.

2D MoS_2-Based Electronic Nanosensors for Rapid PFAS Detection in Water

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Bergen Stem Student Scholar Program [1], Department of Chemicals and Materials Engineering[2]
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Per- and poly-fluoroalkyl substances (PFAS), a large group of persistent anthropogenic organic chemicals widely used in industrial processes and consumer products, have emerged as a significant concern due to their associated health risks; As PFAS molecules do not degrade easily in the environment due to the strength of the carbon-fluorine bonds which lead to bioaccumulation in humans and other organisms. These health risks posed by exposure to PFAS can lead to increased thyroid and cholesterol levels, disrupt hormones which may affect reproductive health, as well as damage to the liver and immune system. Consequently, the United States Environmental Protection Agency (USEPA) and the New Jersey Department of Environmental Protection (NJDEP) have established maximum contamination levels (MCL) for PFAS in communal drinking water: USEPA at 4 parts per trillion ppt for PFOA/PFOS and NJDEP at 13 ppt for PFOS/14 ppt for PFOA. Traditional technologies such as liquid chromatography-mass spectrometry and gas chromatography-mass spectrometry are often impractical for onsite monitoring due to their high costs and the need for professional operation with well-equipped laboratories. Therefore, there is a crucial need for a rapid, simple, portable low-cost sensor for PFAS detection in water.

To address this growing concern, we aim to fabricate a novel field-effect transistor (FET)-based electronic sensor, which has garnered significant interest due to its high sensitivity, low-cost fabrication, scalability in manufacturing, and suitability for rapid onsite testing. The structure of an FET PFAS sensor is depicted in Figure 1. The working principle of the FET sensor relies on the change of channel material conductance upon exposure to the target molecule. Here, lab-grown high-density 2D MoS_2 flakes are used as the channel materials. We developed a hexagonal boron nitride (h-BN)-assisted functionalization process, where h-BN acts as an intermediate layer between MoS_2 and pyrene-based linker molecules to facilitate the selective bonding with various types of PFAS molecules. The fabricated FET sensor will be exposed to different concentrations of PFAS containing water to validate their sensitivity. The selectivity of the FET sensors will be evaluated with a mixed solution containing PFAS and other interference ions or molecules. We anticipate that this work will contribute significantly to the advancement of next-generation electronic sensors, offering a cost-effective, rapid, and sensitive detection tool for in-situ PFAS monitoring in water.

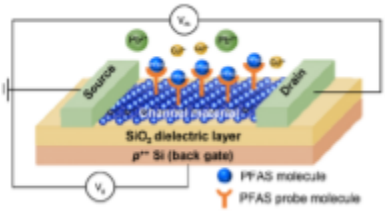

Figure 1. Schematic illustration of a FET sensor for PFAS detection

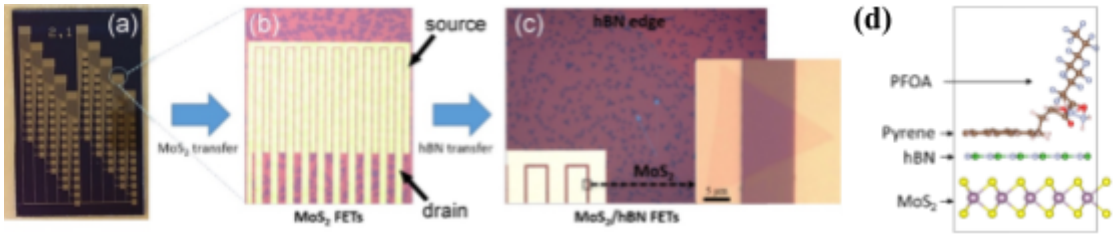

Figure 2. Image showing (a) the as-fabricated sensors; (b) source/ drain electrode pairs, with MoS_2 and h-BN film; (c) one MoS_2 flake in channel area, (d) functionalization process using h-BN intermediate layer and pyrene-based linker

Characterization of Mullins Recovery in Filled Rubbers

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Abstract: Filled rubbers are a commonly used and unique class of engineering materials with special properties. Specifically, filled rubbers experience a phenomenon known as the Mullins effect, characterized by a loss in strength and stiffness after an initial stretch. However, this strength and stiffness can be recovered by another phenomenon known as Mullins recovery, which is usually thermally activated. Recent work has shown a tight coupling between these two phenomena, but few models consider both phenomena simultaneously. This presents an issue when trying to predict the behavior of the material under complex conditions and thus necessitates further research. Since both of these phenomena greatly depend on temperature, this research is focused on creating a reliable and comprehensive experimental study providing novel data on how the coupling between the two phenomena changes with respect to temperature. The experimental study consists of data collected from multiple large-deformation uniaxial tests. First, large deformation uniaxial tests at a quasi-static rate are performed on multiple samples to determine materials original behavior. Then, the samples undergo cyclic stretching in order to induce the Mullins effect. After, the samples are allowed to recover at various temperatures to determine how the coupling between the two phenomena changes with respect to temperature. Finally, another large deformation uniaxial test at a quasi-static rate is applied to the samples to determine the change in the material's behavior and how much it recovered for a given temperature. The results of this experimental study could be analyzed in the future to develop an explanation of the coupling, improve or calibrate models, or further the understanding of the Mullins effect, Mullins recovery, and filled rubbers.

Identification of the Lowest Power Consumption and Multi-Level Cell Characteristics of RRAM Devices

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The traditional architecture that modern computing is based upon uses a separated Central Processing Unit (CPU) and Random Access Memory (RAM). The separation of these two units leads to a bottleneck, which causes a memory wall. Processes like the training of Artificial Intelligence demand large data movement, meaning it is limited by this bottleneck.

In memory computing is a promising new architecture that may be used to substitute the conventional computing systems. The computing in this architecture is performed within the memory. These computations are done using Ohm's law for multiplication and division and Kirchhoff's law for addition and subtraction.

In our lab we use a Metal-Insulator-Metal (MIM) Resistive Random Access Memory (RRAM) stack. By applying an electric field to the top electrode while grounding the bottom electrode, oxygen ions are attracted to the top, which creates enough oxygen vacancies to form a conductive filament (CF) in the oxide, which will lower the Resistance State of the device. This causes the device to enter a Low Resistance State (LRS). When we reverse the electric field being applied to the top electrode, the oxygen ions will move towards the oxide and recombine with the oxygen vacancies, rupturing the CF and entering the High Resistance State (HRS). We are currently testing five devices with TiN as the top and bottom electrodes and ZrO_2-based RRAM devices with different positions of Hydrogen Plasma treatments, as shown in figure 1. Our goal is to find which device is the most stable, and which switches between a LRS and HRS with the least energy, and which shows multilevel cell characteristics.

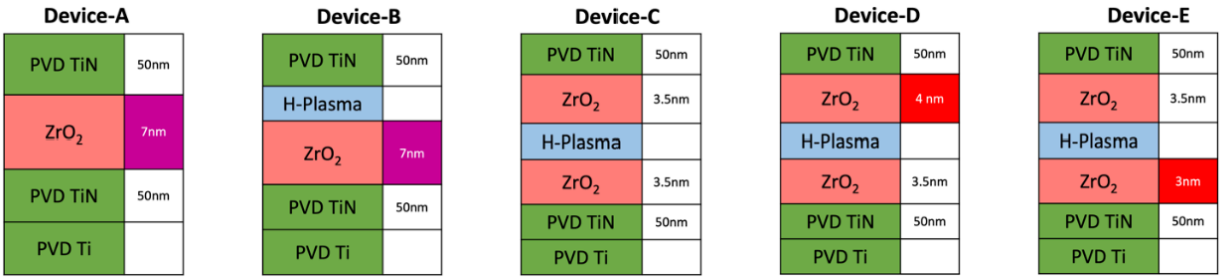

Figure 1. The layouts of the five TiN and ZrO_2 devices being tested.

Rapid Ignition of Reactive Material Powder

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Metal fuels are commonly powders that can sustain combustion reactions. Compared to traditional hydrocarbon fuels (like gasoline and natural gas), metals, such as Al and B, have greater energy density, higher combustion temperatures and distinct reaction mechanisms. Metal fuels are used in solid propellants, explosives, and pyrotechnics, boosting the total energy release for respective formulations. New types of such fuels, including composite materials and alloys, are being developed and should be characterized before their manufacturing is scaled up. This research is developing a novel approach to quantifying both the dynamics and energetics of heat release of metal fuel combustion for small material samples. Current methods are not capable of coupling quantitative measurements of both the reaction rate and the total energy release. The present approach uses a focused electrostatic discharge (FESD) to ignite the powder. The heating occurs within microseconds, approaching the rates relevant for the practical applications. Varying the FESD voltage, it is possible to tune the heating rate precisely. The ignited powder is dispersed to burn inside a small chamber. Its expanding plume is imaged optically, and the generated pressure is measured in real time. The apparatus is aimed to provide a fast, cost-effective method to study ignition delays, burn rates, and released energy for diverse metal-based powder fuels. Over the course of this research, our goal is to identify a relationship between the mass of loaded powder and the rate of pressure rise, peak pressure, and ignition delay, as well as collect and analyze combustion products. Currently, experiments with Al/CuO thermite powder are in progress.

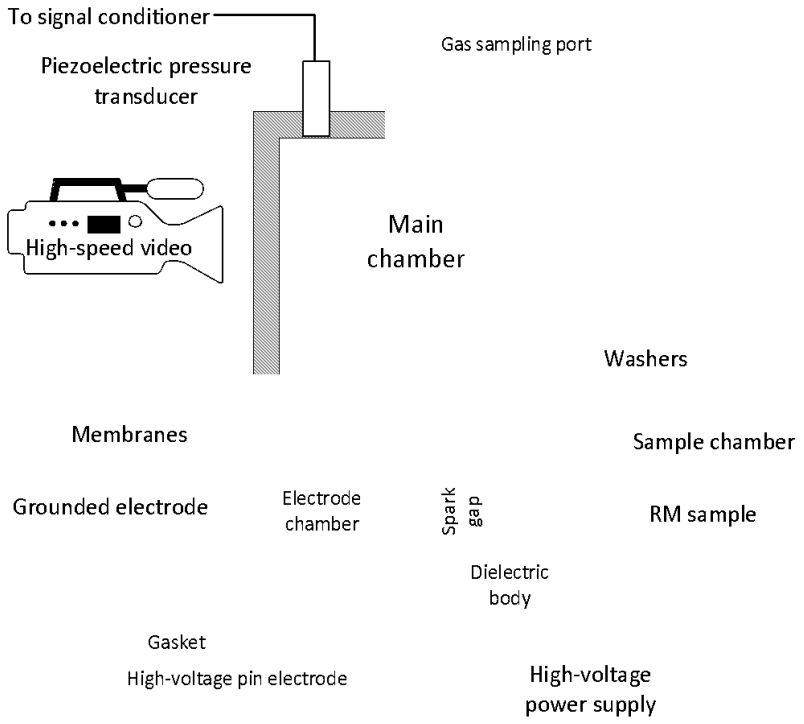

Figure 1: Schematic of Controlled Volume-Electrostatic Discharge (CV-ESD) apparatus

Application and Design of Novel Scaffold Anchoring Devices

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Abstract: Over 4 million reconstructive surgeries are performed each year as a result of injury or damage to skeletal muscle tissue. When 20% or more of the muscle mass is lost, the body is incapable of regenerating the lost skeletal muscle tissue, thereby resulting in a permanent loss of function. Current methods of treatment for these types of injuries include autologous muscle flap transplantation and physical therapy, which are limited by their inability to completely restore muscle functionality. The goal of skeletal muscle tissue engineering is to circumvent these issues to create implantable tissues that facilitate muscle regeneration. In order to fabricate these tissues, muscle construct morphology needs to mimic native skeletal muscle tissue as much as possible. One method of creating this desired morphology is through tension. In this study, we explore how tension distribution impacts the morphology and alignment of skeletal muscle tissue constructs. To do so, we designed and fabricated two novel anchoring peg geometries (Figure 1) and explored how these geometries impact skeletal muscle alignment, using the current geometry (cylindrically shaped anchoring peg) as a control. These anchoring pegs were fabricated using PDMS, and integrated within a custom-built contractile force indicator device in order to apply tension to skeletal muscle scaffolds during a 10-day culture period. Tissue compaction and compaction forces were measured throughout the culture period via recording displacement of the mobile peg. After the culture period, the scaffolds were fixed, immunostained against myosin heavy chain and counterstained with actin and DAPI to quantify myofiber morphology, alignment, and maturation. This project will contribute towards finding an optimal method for the application of tension and will further define how tension impacts myofiber morphology.

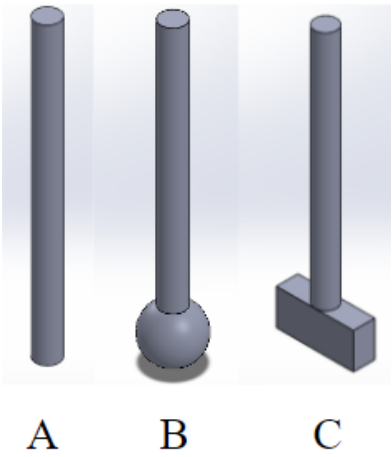

Figure 1: Depiction of the various peg geometries. [A] cylindrical peg design (positive control). [B] spherical-shaped peg design. [C] T-shaped peg design.

The Combined Effect of Non-Steroidal Anti-Inflammatory Drugs and Growth Factors on Axonal Growth

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Abstract: Peripheral neuropathy, a debilitating condition arising from various injuries and diseases, poses a significant challenge despite the peripheral nervous system's inherent regenerative capacity. While autonomous regeneration occurs, the healing environment is often suboptimal. Current treatments, such as autologous nerve transplantation, fall short of achieving full functional restoration and are hampered by issues like neuroma formation, donor site morbidity, and the prolonged management of newly formed surgical sites. In existing literature, brain-derived neurotrophic factor (BDNF) and glial cell line-derived neurotrophic factor (GDNF) have been demonstrated to enhance nerve regeneration. However, these growth factors have not been explored in conjunction with non-steroidal anti-inflammatory drugs (NSAIDs), of which our lab, and others, have identified can stimulate axonal growth. Both NSAIDs and growth factors independently promote axonal growth, and there is theoretical potential for synergistic effects between the two in peripheral nerve repair. In this proposal, we aim to address this knowledge gap by investigating the combined impact of NSAIDs and growth factors, specifically BDNF and GDNF, on axonal growth from dorsal root ganglia explants. The long-term goal is to improve severe nerve injury treatment by advancing understanding and developing innovative strategies.

Synthesis of Red-Absorbing Photosensitizers for Artificial Photosynthesis

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Abstract: The burning of fossil fuels contributes to anthropogenic climate change. Solar energy presents a clean and sustainable alternative to nonrenewable energy sources. A challenge in converting and storing solar energy is the relatively low abundance of higher energy photons in the solar spectrum. Red light in particular is abundant in solar radiation but not absorbable by existing ruthenium polypyridyl chromophores, which absorb light at lower wavelengths. To address this limitation, we are working on the synthesis of molecular chromophores capable of absorbing light at different regions of the electromagnetic spectrum. An objective of our research is to use two chromophores to broaden the wavelength range of solar photons which can be captured and used for useful work. Unlike ruthenium-based chromophores, squaraine chromophores are capable of absorbing photons in the red/near-infrared range. We therefore examined the existing literature and identified two target chromophores for synthesis: a squaraine dye that absorbs lower energy red/near-IR light and a ruthenium-based dye that absorbs higher energy light at around 460 nm. We are synthesizing these compounds using organic and inorganic synthesis techniques and confirming our products through NMR spectroscopy. These chromophores will ultimately be installed on a TiO_2 electrode surface to allow for light-initiated electron transfer to the cell. This coupled dual chromophore model should be capable of absorbing a broader range of wavelengths than either chromophore individually. We plan to use transient absorption spectroscopy to evaluate the performance of our system.

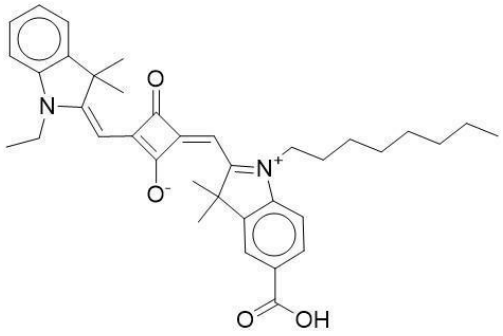

Figure 1: Structure of target squaraine dye based on Yum et al. (2007)

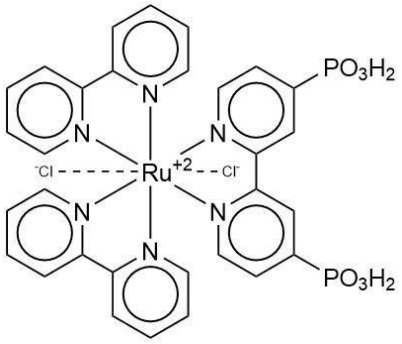

Figure 2: Structure of target ruthenium polypyridyl dye based on Norris et al. (2013)

Amyloid Toxicity: Structure and Size of Toxic Amyloid Aggregates

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Abstract: Amyloid peptides, when they aggregate, can form pores on the surface of a lipid bilayer, impairing the cell, and potentially killing it. These aggregates can vary in size from oligomers containing just a few peptides, to mature fibrils, carrying up to thousands of peptides. Individual peptides, i.e., monomers, do not cause any damage to the lipid membrane. Similarly, when the aggregates are large enough, they are mostly inert. However, starting at a certain size, oligomers begin to form pores in the membrane (Figure 1). This threshold of the minimum number of peptides required to begin damaging the membrane is unknown. Fortunately, with modern simulation technology finding this threshold is a possibility, and the objective is to find not only the minimum size to cause damage, but also the associated oligomer structure and why this specific size and structure cause damage. If this is found, medications and other treatment options may be used to inhibit this aggregate formation and prevent brain damage as seen in patients with Alzheimer's disease. Furthermore, the understanding of why these neurodegenerative diseases occur and what causes them can be further clarified and refined, helping make better treatments and possibly cures. The project is conducted through performing many molecular dynamics simulations using GROMACS software. At first, 10 peptides in a beta sheet were placed in simulations with a lipid membrane, and in other simulations 6 peptides. Ten peptides are expected to easily penetrate the membrane, while for 6 peptides it may take much longer, if pore formation even occurs at all. Based on these results, simulations with more or less peptides may be run to find the minimum aggregate size that causes damage. When it is believed that a minimum size has been found, a subsequent analysis can take place, and we can visualize the structure with the help of Visual Molecular Dynamics (VMD).

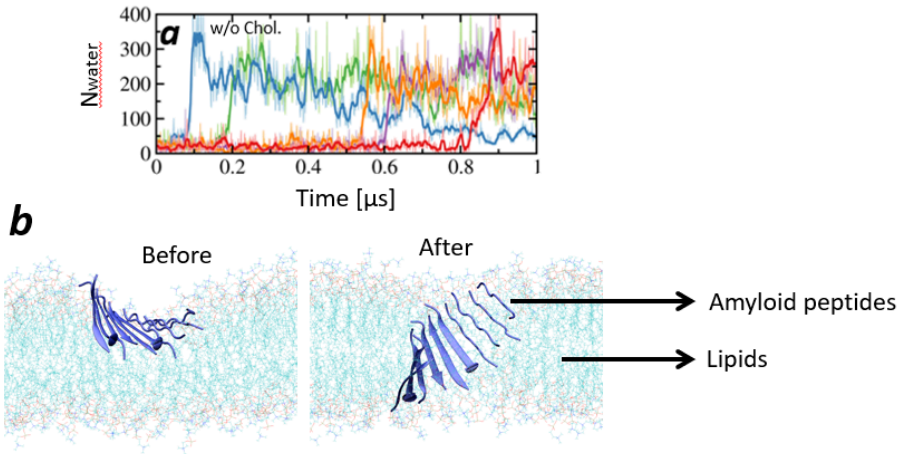

Figure 1: Membrane damage by a small oligomer made with ten amyloid-like peptides. (a) Number of water molecules within the bilayer in 5 independent simulations. An increase in Nwater shows penetration of the oligomer. (b) Characteristic structure of the oligomer before and after pore formation.

Prompt Optimization for Secure Generation of Functional Source Code with Large Language Models (LLMs)

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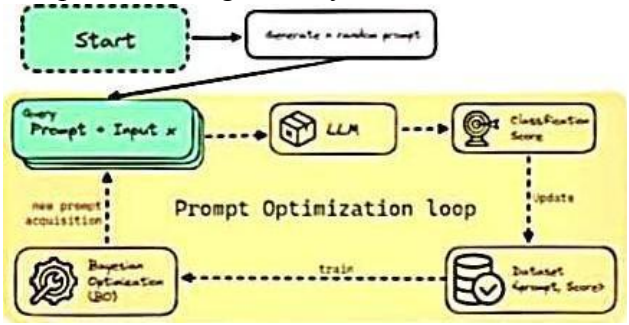
New Jersey Institute of Technology, Newark NJ 07102

The rapid advancement of Large Language Models (LLMs) like GPT-4 has revolutionized various domains, including code generation. However, the generated code often lacks the necessary security measures and optimization, which can lead to vulnerabilities and inefficiencies. This research addresses the critical need for a framework—PromSec—that ensures the generation of secure, functional, and optimized source code using LLMs.The significance of this research lies in mitigating the risks associated with insecure code generation. In an era where cybersecurity threats are escalating, ensuring the integrity and security of automatically generated code is paramount. The primary goal of PromSec is to enhance the prompt engineering process, leading to the creation of source code that is not only functional but also secure by design. Our research methods involve a combination of prompt optimization techniques and security validation protocols. We employ an iterative approach to refine prompts, integrating security guidelines and best practices into the prompt structures. The experimental design includes benchmarking generated code against established security standards and functional requirements. Additionally, we develop a prototype tool that automates this optimized prompt generation process.While the final results are forthcoming, we anticipate that PromSec will significantly reduce the incidence of security flaws in generated code and improve overall code quality. In conclusion, this project paves the way for safer Al-driven code generation. Future work will focus on expanding the scope of security checks and refining the prompt optimization algorithms to adapt to evolving security threats.



Mathematical Modeling and Data Analysis in Computational Psychiatry

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The brain is a powerful but complex organ which makes understanding brain activity with regard to the cause and effect of mental disorders challenging. Computational psychiatry is a field that seeks to break its complexity with mathematical modeling. A previous study in this field (Lam et al, 2022) relates the synaptic balance of excitation and inhibition (E/I) to the onset and degree of relapse of mental disorders, especially in patients with schizophrenia. The cause of schizophrenia, though unknown, is dependent on environmental and genetic factors, which are both impacted by the circadian (24-hour) cycle. However, understanding how the E/I balance fluctuates over a circadian cycle is still unclear. Our research aims to explore the diurnal variations in E/I balance and their implications for human behavior. We analyze neural data to quantify the relative activity of excitatory and inhibitory neurons at different times of the day. Using Brian, a Python package for simulating large neuronal networks, we develop computational models that simulate E/I balance dynamics based on circadian rhythms as external factors. We model how the light/dark cycle affects E/I balance by adjusting the strength of excitatory NMDA synapses and inhibitory GABA synapses. We expect to observe distinct patterns of firing activity across the day, with potential implications for decision-making abilities. Our models will provide insights into how circadian variations affect schizophrenia symptoms.

Geographical Data Visualization and Analysis for Roman Street Shrines

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Abstract: Rome houses hundreds of Christian street shrines. These shrines are one expression of a global phenomenon of informal devotional practices that take place in public spaces. In Rome, as elsewhere, devotees leave votive offerings — inscriptions, candles, flowers — at these shrines. The Rome Research Group tracks this activity, having collected data on over 670 shrines. This data includes information pertaining to the images, architectural styles, physical attributes, and location of the shrine and the building and street it occupies. The data is stored in a relational database that allows for shrines to be queried for their attributes. Such queries are then spatially mapped in ArcGIS. Creating a secure, public-facing, interactive and collaborative geographic database is challenging. Our approach is novel. It foregoes external hosting on researchers' personal websites, instead utilizing the university's own network with SharePoint, Azure SQL Server, and ArcGIS. Unlike the former approach, this allows us to maintain security on the data and remain closely affiliated with NJIT. We are currently examining how tourism affects devotion with two proximity analyses: proximity to major tourist monuments and proximity to public transit. Preliminary findings indicate a significant decline in devotion for shrines near tourist attractions. The total devotion rate at shrines within 300 meters of a tourist attraction (~10%) is about half of the average for the whole city (~20%). Overall, mapping active shrines reveals that, within the historic city center where the most famous tourist attractions lie, there is only sparse devotion. In the city's newer 20th-century neighborhoods, which receive little to no tourism, there is a much higher devotion rate. Our database will allow researchers to perform the analysis needed to more precisely describe how tourism is impacting religious practice.

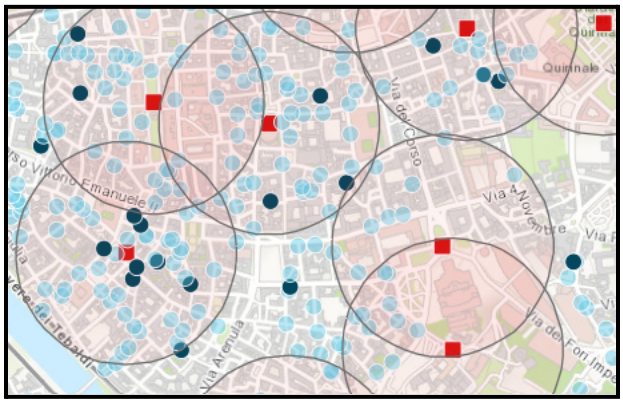

Figure 1: A selection of shrines in the high-tourism historic city center.

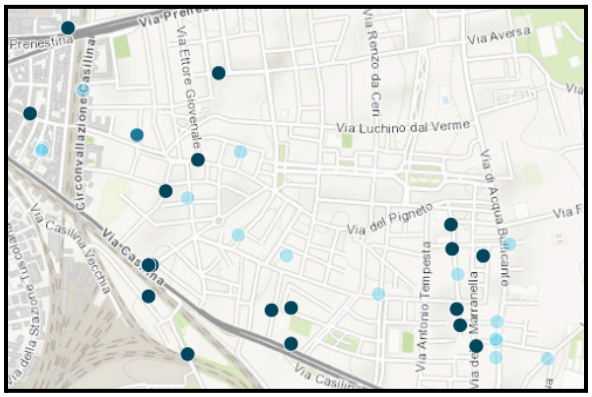

Figure 2: A selection of shrines in the city periphery, far from tourism.

Zero-Shot Audio Classification Without Audio Training

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Abstract: This research aims to test the competence of Large Language Models (LLMs), such as ChatGPT, on audio classification. More specifically, the extent to which language models classify audio through the input of high-level acoustic features. This includes features in the domain of rhythm, tonality, harmonic content, spectral shape, and envelope characteristics. The type of classification executed by the LLM is defined as zero-shot training whereby audio data is not present during training stages. The motivation for zero-shot is to remove the training typically needed when developing audio classification models. LLMs can potentially skip this step by leveraging the information contained within their knowledge base. There could be a situation in which the LLM has such rich knowledge within its scope that training it with further examples is simply a waste of time and resources. To understand how much ChatGPT knows, the first step is to input a generic unbiased prompt of different sounds (in the dataset ESC50) and ask it to describe the respective high-level audio features. This information was used as a guide to indicate what features were needed to be extracted. Using audio extraction tools such as the Python library Essentia, values of different features were computed and therefore fed back into ChatGPT. These audio details were communicated in the form of raw numbers, statistics, mappings of statistics, high-level attributes, or how a person would describe sound. In addition, ChatGPT's performance will be evaluated when the context of where the sound occurs is given. The accuracy of the zero-shot audio classification from the LLM will be compared to other zero-shot audio classification models.

Examining Ability Bias in Large Language Models

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With the growing usage and popularity of Large Language Models (LLM), it is important to ensure that a proper response is generated regarding diverse populations of people. Current research on LLMs has found that the responses may have implicit biases and assumptions about gender, race, and religion. Some research is also beginning to suggest how assumptions about people with disabilities might also be encoded in LLMs, yet we lack an in-depth exploration of the types of assumptions they encode about people with different abilities. If not careful, users will normalize these responses which can become somewhat harmful. In this work, We analyzed three different patterns of ChatGPT responses for situations where the model was asked: a) why it returned a particular response, b) was there any assumption (and bias) in the response, and c) how would it rewrite its answers. Through this work, we provide preliminary insights on how LLMs represent people with disabilities and examine if assumption and bias questions can be a useful strategy for minimizing harmful stereotypes encoded in these AI tools. Future work will be motivated to figure out how to minimize these biases and assumptions by reconfiguring some of the prompts inputted through the platform and will observe what type of responses ChatGPT will provide.

Dynamical Systems in Computational Psychiatry

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In computational psychiatry, excitation-inhibition (E/I) balance is defined as the ratio between the firing of excitatory pyramidal neurons and inhibitory interneurons. Current research suggests E/I balance can change throughout the day and plays a key role in mood disorders such as schizophrenia. However, how changes in E/I balance throughout the day contribute to symptom timing and intensity is not fully understood. To address this gap in knowledge, we investigated dynamical mathematical models that capture the impact of E/I balance on decision making. We selected a low-dimensional model to facilitate the use of bifurcation theory, which focuses on the qualitative behavior of dynamical systems. Since it is believed that the amount of inhibition changes based on a circadian (24-hour) oscillator, we used the inhibitory synaptic conductance as a bifurcation parameter to see how it affects the behavior of the model. These results can then be used to explain findings regarding the timing and intensity of symptoms of schizophrenia patients and propose possible interventions to keep symptoms in check. Because sleep disruption is common in people diagnosed with schizophrenia, future work may involve modeling how sleep disruption affects the circadian oscillator and E/I balance as a result.

Examining Relationships Between Mood and Music Listening Habits

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Abstract: Prior research has examined the influence music has on a person's mood, especially on its function as stress relief. However, this data is usually collected in an artificial, experimental setting, and often uses a small collection of music chosen specifically for the study that may not match a user's personal music preferences. This project will construct open-source tools capable of approaching these ideas from a more organic perspective, partly through use of the music streaming platform Spotify. Spotify analyzes every song on their database algorithmically, judging six attributes of a song: acousticness, danceability, energy, liveness, speechiness, and valence. A survey will be constructed and prepared for distribution, usable by anyone with a Spotify account. The survey will collect each user's top 25 songs and their corresponding analyses over the last month. In addition, the survey will prompt users to give an overview of their most dominant moods over the last month, selecting from a list of common mood descriptors such as "happy", "anxious", etc. The given tools will then organize collected data into a format that could be useful for correlational statistical analysis -- for example, finding which mood corresponds to the highest average "energy" score in a given dataset. This study will create a method to illustrate in a greater light one of the many influencing factors on the ways in which we consume art. In the future, these tools could be adapted for alternative approaches to this quantitative research, ideally asking users to repeatedly take a diary of their mood over a sustained period, to ensure that the mood data is as accurate as it can be.

Are human interaction biases employed when using cross-species communication signals?

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When texting, people automatically adopt similar grammar and emoji use as their partner, almost as if following an unspoken rule. This type of alignment behavior is pervasive in various types of social interactions from daily conversation to dancing. It is unknown if alignment is a result of humans' sophisticated linguistic communication or whether it is a characteristic of our basic social cognition and thus a possible precursor to language. To investigate this, I am helping to code an online experiment to explore the extent of nonlinguistic alignment. In the planned study, participants will interact with a computer partner using birdsongs in order to distinguish between linguistic and social motivations in interactions. In addition to looking at whether such alignment is present when humans communicate using birdsongs, the experiment will investigate how alignment occurs, by manipulating interaction structure and using songs that vary in duration and complexity. This past spring I analyzed data from a previous study that verified that humans can perceive these features for my STS 205 independent research. For the present project, I am learning JavaScript (jsPsych) and taking a modular approach to building the subtasks of the planned experiment. The results of the study could help to provide a better understanding of the social factors behind the evolution of language.

Automation and Data Processing for Sorption-Ultrasonics Experiments

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Abstract: Nanoporous materials can be filled by fluids in many material applications. Many thermodynamic and mechanical properties of these fluids are changed when confined in a nanopore compared to in bulk. These fluids inside a material's nanopores can change many properties of the material itself. The process of a fluid confining within a material is called absorption, and the reverse process is called desorption. To figure out how the elastic property of the combined material changes, the speed of an ultrasonic pulse sent through the material can be used. The ultrasonic pulse transmission technique is a non-destructive method of measuring the elastic properties of materials. This process sends an ultrasonic pulse through a material, and the speed of the pulse, as it transverses through a material, correlates to the material's elastic properties. This method consists of a transducer that sends an ultrasonic pulse through a material, a transducer that receives the pulse as it passes through the material, and an oscilloscope that collects the ultrasonic data and sends it to a computer (Figure 1). From this ultrasonic data, the main objective is to find the time it takes for the pulse to travel through the material, which is called the time of flight. The time of flight of the pulse can be calculated by measuring the time delay between relatively similar points on the transmitted and received pulses (Figure 2). Using the calculated time of flight and the measured length of the material, the speed of the pulse can be calculated, which can then be used to find the elastic modulus of the material. This process of analyzing and calculating the time of flight from the ultrasonic data is to be automated to swiftly and efficiently complete the Data Processing. Using Python, the data from the oscilloscope can be graphed to be viewed visually, and the calculations required to calculate the time of flight and modulus can be automated. This can be done by programming code to automatically find relative points on the transmitted and received pulses, such as minimums or maximums, and compare them to each other to find the time delay between them (Figure 2). By streamlining the Data Processing, the results can be achieved quickly and accurately, reducing the manual labor and possibility of errors typically present. In future advancements, the entire process including the execution of adsorption and desorption may be completed autonomously, leading to a greater number of trials and more accurate results, which would overall give us a greater understanding of elasticity of nanoporous materials with confined fluids.

Figure 1: Model of Pulse Transmission

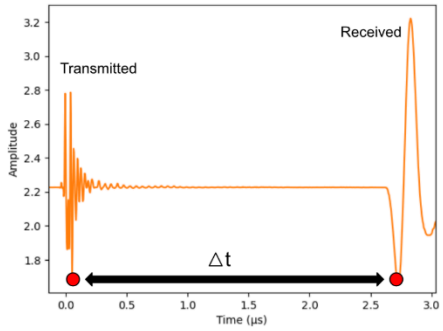
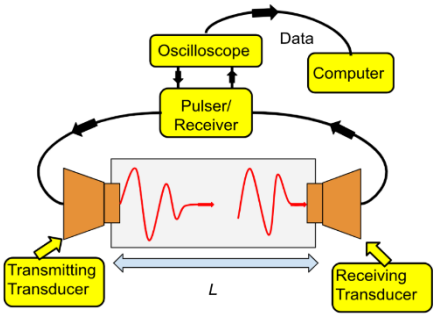


Figure 2: Graph depicting how the time of flight is calculated



Increasing Digital Accessibility of NJIT's Online Learning Presence

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With the rapid shift to digital learning caused by COVID-19, ensuring that online educational resources are accessible to all students has never been more important. This project aims to identify current challenges faced by students with alternative learning needs at NJIT, evaluate the effectiveness of NJIT's current strategies, and propose solutions to improve digital accessibility at NJIT. All students deserve equitable access to digital educational resources and opportunities, no matter how their circumstances affect their learning.

We will employ a mixed-methods approach to achieve these goals, combining qualitative data collection and quantitative data analysis. Our methodology includes three key components: First, we will interview relevant faculty members to understand how NJIT currently addresses digital accessibility and its strategies. Second, we will issue three surveys: one for students to assess general awareness and experiences regarding digital accessibility, one for students with alternative learning needs to pinpoint more specific challenges, and one for faculty to assess their understanding of good practices regarding accessible content creation. Lastly, we will perform a comparative policy review, using data gathered previously to examine NJIT's current strategies addressing digital accessibility and compare them with practices implemented at other postsecondary institutions in order to determine any improvements that NJIT could make or strategies that NJIT could implement to increase digital accessibility.

Our research will reveal significant insights into the existing accessibility gaps and provide recommendations to improve NJIT's digital accessibility for students with alternative learning needs. We will provide a detailed assessment of NJIT's current practices and challenges that students face regarding digital accessibility, propose new practices for creating digital content and ensuring its accessibility, and provide recommendations for improving digital accessibility policy. We aim to foster a more inclusive and equitable online learning environment at NJIT by implementing these three strategies. In the future, we will focus on implementing the proposed strategies and developing a new online interface to make digital accessibility tools readily available to those who need them.

Fast computation of differential geometry operators on discrete surfaces

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The ability to accurately and efficiently calculate geometric features of discrete surfaces, such as curvature and the normal and tangent vectors of a surface, is essential in many computational fields, notably fluid dynamics/simulation, animation, and denoising/image smoothing. The goal of this project is to investigate and develop more accurate, more efficient, and/or faster methods for calculating differential geometry operators, in particular curvature and the surface gradient. We have developed one method of approximating curvature in 2D and 3D (mean curvature) and two methods of approximating the surface gradient in both 2D and 3D. The general equations used to calculate curvature and the surface gradient typically use the derivatives of the function that defines the curve or surface and the partial derivatives of the scalar field that the curve or surface occupies. These derivatives have been approximated using various central difference methods in our estimations. Recent developments in Volume of Fluid (VOF) method estimates using machine learning have produced promising results and are the basis of our work in the coming weeks. In the VOF method, a 2D-plane containing a curve or 3D-space containing a surface is evenly segmented, and each segment (typically a square or cube) is assigned a value based on how the curve or surface intersects the segment. The machine learning aspect of this method uses circles (2D) or spheres (3D) to provide exact curvature when training the neural network. After the training phase, we will observe how well the method approximates curvature and compare it to our other approaches. We will also continue to investigate different methods of improving the results of our current implementation such as using more precise floating point numbers (when reasonable) to improve accuracy, using less precise floating numbers (when reasonable) to improve speed, and consistently reassessing our programming approaches to improve efficiency by using less computational resources.

Zero-Shot Generalization Analysis

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Introduction:
This research project focuses on evaluating the zero-shot generalization capabilities of current audio-language models, semantic embeddings, and multimodal models. Zero-shot learning aims to classify inputs into classes that the model has not encountered during training, typically through cross-modal techniques. Despite numerous claims of zero-shot abilities, many evaluations appear flawed due to class overlaps between training and evaluation datasets. This project seeks to address these inconsistencies by systematically analyzing existing literature, conducting evaluations of publicly available models, and proposing new datasets to improve the evaluation of zero-shot audio classification systems.

Research Methods:
To begin, using the PRISMA 2020 guideline, a comprehensive literature review was conducted, sourcing approximately 600 articles from ACM, Google Scholar, and IEEE. This list was refined using keywords such as "audio, zero-shot, cross-modal," narrowing it down to articles directly relevant to zero-shot audio classification. Each article was examined for details regarding the datasets used for training and evaluation, pre-training datasets, availability of code, and measures taken to mitigate class overlap.

Our approach involves:

1. Analysis of Existing Literature: Reviewing research papers to identify the prevalence of poor evaluation practices, particularly those involving class overlap in datasets.
2. Dataset Creation: Developing a new dataset free from class overlap with major audio datasets used in model training. This ensures a true zero-shot evaluation setting.
3. Model Evaluation: Assessing publicly available zero-shot audio classification models using the newly created dataset to provide an understanding of generalization abilities.

Anticipated Outcomes:
We anticipate that this research will highlight significant gaps in current evaluation practices, demonstrating the extent to which class overlap affects the validity of zero-shot claims. By creating and utilizing a new, overlap-free dataset, we aim to provide a clearer picture of the true capabilities of these models. Furthermore, we expect to propose practical solutions for improving zero-shot evaluation methods, contributing to the advancement of machine listening technology.

Conclusion and Future Work:
This research is crucial for advancing the field of machine listening, addressing the challenges of data scarcity and ensuring robust evaluation methods. The outcomes will provide valuable insights into the state-of-the-art in zero-shot audio classification, guiding future research and fostering the development of more reliable and effective models. Future work will focus on refining the proposed solutions and exploring their applications in various domains, including urban planning, healthcare, and environmental monitoring.

Smart Eyewear For Patient Registration

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Abstract: Each year, it is estimated that 371,000 deaths were due to misdiagnosis, in addition to 424,000 with permanent disabilities. These numbers are considered to make up part of the 11% chance a doctor could potentially make a mistake; resulting in misdiagnosis. With the pain potentially being subjected toward a loved one or stranger, many medical professions are trying to find a solution to try to improve their technique into diagnosing and treating patients. Furthermore, with the number of physicians plummeting, many facilities are lacking professionals to help take care of patients. With all of this being said, what if there was a way to increase the diagnosis success rate as well as help substitute the loss of the needed physicians? Utilizing these questions, we have come up with a way for patients to be registered and accurately diagnosed without having to use too much man power. The solution was to specifically use a portable system that would help perform these tasks. This resulted in us looking into the lens and its potential benefits. Before working on the lens, we thoroughly looked into technology revolving cameras to specifically understand how lenses were used. We looked into specific hardware such as “Sony Mirrorless Cameras” to see how they used their face registration feature to help track people in front of the camera. We even looked into outside tracking and inside tracking to see how these features could benefit the user. However, the area that really started to peak our interest was ARVR (augmented and virtual reality). ARVR introduced the use of applying digital content in both the physical and virtual worlds. This would, in theory, allow physicians to open records on patients that have attended the facilities. Another aspect that we are trying to look into is technology systems that could help detect and monitor heart beats. This could not only make check ups and maintenance over patients easier, but this could help save lives during emergency situations. We have also been looking into machine learning algorithms to help the system operate on these specific tasks. With all of this being said, our main priority is to now put all of these ideas and theories into practice while making the whole process portable through eye wear. Even though these steps and ideas seem really put-well together, putting them to action will be very challenging for us all to do. However, we will continue in researching and experimenting on other methods that could either help our current steps or innovate on ideas that could eventually replace the methods we have already come up with. With our remaining time, we will continue pursuing the steps that were laid out.

Cost-effective Service considering Passenger Waiting Time

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Every year, millions of passengers lose productive time waiting for buses or other forms of public transit, which is frustrating. While bus service stakeholders aim to maximize profits, potentially neglecting users' benefit such as wait time. In order to design an optimal service, this study intends to minimize total cost, consisting of supplier cost and user cost, considering realistic waiting time. A mathematical model will be formulated and a solution method will be developed to optimize bus service frequency, subject to practical constraints. A numerical analysis is conducted under various operation scenarios. The results will suggest that the optimized service may yield the best service at least cost. The sensitivity analysis is conducted, and the impacts of model parameters on decision variables to the cost of operation will be explored.

Digital Twins and Smart Home Architecture

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The goal is to create a closed-loop system for ventilation and temperature control using the YoctoPuce temperature modules and hub interface, creating a Digital Twin framework that will allow for bi-directional control of the system and simulate possible room conditions based on user actions. This push is a part of the mission of Siemens to broaden its connection to civilian and industrial spaces as Smart homes/Smart facilities are an integral part of Siemens's mission for a green energy future. Digital Twins are efficient in optimizing the management of semi-controlled environments, allowing for increased energy efficiency and comfort for those inside the building. The bi-directional control of the system will allow the admins of the system to facilitate real-world adjustments based on the recommendations derived and simulated by the model. The usage of this Digital Twin will allow for an increase in comfort, efficiency, and stability in the usage of temperature systems throughout our society. While conventional wisdom would indicate that this system is very similar to standard air conditioning systems found in almost all buildings, this project is more ambitious than just being a digitized version of the system we see everywhere.

This system will include all methods of heating and cooling available in the room, such as shutting off an idling computer in order to lessen the heat generated by the objects in the room while displaying that option inside the digital version of the room. This will be achieved by pairing the sensor apparatus with sensors to detect the state of the room and microcontrollers to enable the switching on and off of any electronic component and allow the digital model to receive the signal. The simulations will be performed using an open-source software known as Modelica which will be able to perform the necessary ventilation simulation with inputs from Yocto-Meteo-V2 paired with the YoctoHub-Wireless-n. This system will be a living environment, allowing for a change in the heating and cooling elements available to the simulation system in real time through detection from the sensors in the room. This will allow the Digital Twin simulation to make changes where necessary to accomplish the intended temperature change, without being a static model that would break if any of the intended heating or cooling sources were to go non-functional or be removed entirely.

Applying Parallelism to Optimize the Backpropagation Algorithm

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Over the past decade, machine learning has grown to become one of the most widely used technologies. From the large language models that help power our chatbots to the pretrained transformers that give life to our generative systems, machine learning architectures are prevalent in both consumer and research applications. These large architectures, however, are typically inefficient when training on standard datasets, which can be terabytes in size. Processing such a large amount of data can cause practitioners to incur significant operational costs.

This project seeks to reaffirm that through data parallelism, or the concurrent processing of data, the efficiency of training a machine learning model can be vastly improved. The initial focus of the project will be on conducting a comprehensive analysis of the backpropagation algorithm in an effort to identify areas where it could benefit from parallelism. Ultimately, the project hopes to take advantage of this analysis, along with NVIDIA's CUDA programming interface and the Single-Instruction Multiple-Data (SIMD) architecture of graphics processing units (GPUs), to develop a vectorized implementation of the backpropagation algorithm for the Scikit-learn library. Upon its implementation, an empirical analysis will be conducted on the vectorized method to determine its runtime and parallel efficacy.

Photorealistic Virtual Environments and Visual Clutter

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This research is focused on reducing visual clutter in immersive environments. When there are too many visual elements, it becomes challenging to concentrate on important information and complete tasks efficiently. Current visualization technologies need improvements to effectively present information while minimizing clutter. This study also explores the effective pipeline of using/deploying photogrammetry models in VR and AR environments. Specifically, it investigates methods, standards, and parameters for optimizing geometry and developing visualization strategies in photorealistic 3D virtual reality environments created using photogrammetry software such as the KIRI engine. It also involves altering and optimizing textures and 3D models using AutoDesk Maya and Substance Painter. User studies will be conducted to evaluate the effectiveness of these visualization strategies in enhancing navigation, task performance, and user experience. The expected outcomes include guiding technological development to improve efficiency by reducing the adverse effects of visual clutter and developing strategies to address visual overload.

3D Environment Optimization for Virtual Reality

Angelina Marie De Guzman, Advisor: Richard Thompson
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As the virtual reality industry advances and expands, so does the need for its development to grow alongside it. This research aims to thoroughly examine aspects of the 3D environment workflow and how to optimize them best for virtual reality (VR) experiences. The research also seeks to discover what level of detail in regards to photorealism can be accomplished without sacrificing the VR application's performance. Three models of the same environment will be created, each representing a more extensive design process than the last. The increase in complexity within these levels will also serve to achieve a more true-to-life and photorealistic appearance. The levels will then be imported into a VR experience, where its CPU and GPU resource intensity will be measured. Performance will be gauged on the VR headset, Meta Quest 3. Many of the current research regarding optimization in VR refer only to visual quality or seek to optimize at the end as a way of troubleshooting non-optimal builds. Testing aspects of a 3D environment (e.g it's geometry, textures, and lighting) in such a way can create informed decisions in the future by designers to save both time and resources. Though it is expected for the "lowest" visual level of detail of the environment to run the smoothest, techniques to boost performance may be able to make the most detailed levels still accessible.

Generating and Validating 3D Magnetograms for SOHO/MDI using A Machine Learning Method

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Mentors: Yan Xu, Haimin Wang
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Strong solar eruptive events often lead to more significant space weather effects, which negatively affect the Sun-Earth environments. Such events are mainly powered by solar magnetic energies. Unlike the Solar Cycle 24, the previous Solar Cycle 23 (1996 to 2011) has been much more active. Unfortunately, a magnetogram archive for Cycle 23 collected by the Michelson Doppler Imager at SOHO spacecraft (SOHO/MDI) only has line-of-sight (LOS) magnetograms available, therefore detailed analysis of magnetic topology can not be done for Cycle 24. Luckily the use of generative artificial intelligence models could allow us to make up for missing data. In my project, I will use a machine-learning Python code (MagNet), developed by researchers in the Institute for Space Weather Sciences (ISWS), to generate 3D magnetograms for the previous more active Cycle 23. MagNet takes inputs of the MDI LOS magnetograms and optical image in the Hα band, which is a good proxy of magnetic field orientations. The MagNet code can then generate Bx and By components of the magnetic field for any given active region. In my project, I aligned SOHO/MDI images, accessed through the Joint Science Operation Center (JSOC) database, with the Hα images collected by Kelzerhone Observatory and Big Bear Solar Observatory. I developed an automatic method, using both Python and IDL, to select the active regions from full-disk images using NOAA's SRS files. I specifically focused on the AR10486 between October 28, 2003, and November 4, 2003. During this period, AR10486 produced a series of strong flares, including the largest X28 flare in recorded history. I plan to input the aligned pair of images of the AR10486 into the MagNet. Successful generation of Bx and By components will allow us to perform a scientific analysis of this famous active region, such as the variation of free magnetic energies. More vector magnetograms will be generated using this method to expand the database of 3D magnetograms for decades of data, which will enhance our understanding of the strong solar activity and eventually predict them.

Assessing Vergence Speed from Virtual Reality System and Vergence Facility as a Potential Biomarker for Concussions

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Department of Biomedical Engineering
New Jersey Institute of Technology, Newark NJ 07102

This research aims to determine if a 12 base out, 3 base in prism can be used as a tool for clinicians and coaches when assessing concussions by determining if vergence speed is a biomarker for concussions. The prism is a portable, inexpensive tool that can determine the participants' vergence speed. The peak vergence velocity is much lower after a participant has suffered a concussion. The peak vergence velocity obtained from a virtual reality (VR) ISCAN eye tracker will be compared to the results obtained from the prism set. The data collected from 38 controls and 59 concussed participants (mean age 17.0 ± 3.4 years) will be analyzed using MATLAB code that is already written and receiver operating characteristic curves will be generated. SPSS will be used to study the ROC curves which will assess the performance of the prism as a diagnostic tool for concussions for the determination of the optimal sensitivity and specificity. Through these results, we will determine if the prism is a viable tool for assessing concussions.

Figure 1. Experimental set-up for vergence facility and virtual reality testing

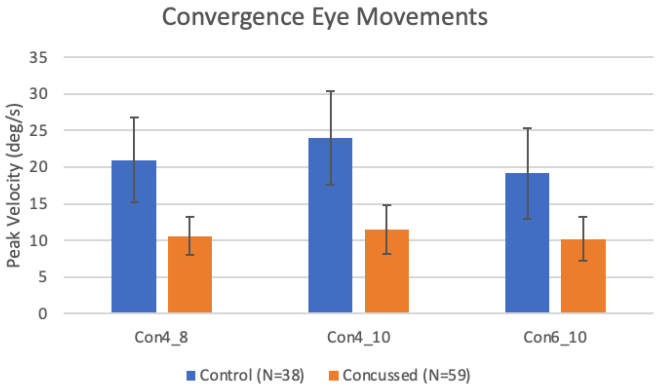

Figure 2. Comparison of average peak velocity for convergence eye movements in control (N=38) and concussed (N=59) participants

Personality Classification Using Natural Language Processing

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Abstract: Modern chatbots and AI assistants are often trained on LLMs, or large language models, like OpenAI's GPT-4 and Meta's LLaMA. They continue to grow in usage in industries such as customer service, mental health, and education by attempting to assist users through personalized interactions. In order to boost the effectiveness of such models, which are often shrouded for proprietary reasons, it is crucial to improve their understanding and adaptivity toward users. Techniques utilizing natural language processing (NLP) to understand human language in such a way have often involved sentiment analysis, whereas research on other methods like personality detection remain limited in comparison. The Big Five personality traits (openness, conscientiousness, extraversion, agreeableness, and neuroticism) are a grouping of psychological characteristics that aid in measuring differences in individuals' personalities. This research seeks to recreate the results of a previous study that instead analyzed the Myers–Briggs Type Indicator system for indicating personality, whose scientific validity is widely disputed. To ensure an NLP model effective at understanding nuances in text and reinforce the idea of user adaptiveness, this research will compare the pre-trained transformer model XLNet with more traditional, less computationally-expensive NLP models using a known dataset of Big Five personality types and their corresponding user-written text. The accuracy of these models after training will be tested with a similar dataset of human text. By evaluating which approaches effectively provide the most accurate results for classifying personality, this research will contribute to the growing field of user personality detection and assist in the development of NLP models. In the future, this may allow LLMs to generate more helpful text output to chatbot users while maintaining transparency and reducing bias.

Using AI Prediction & Genetic Analysis of the Protocadherin Gene Cluster to Improve Diagnosis Yields of Pathogenic Variant Carriers in Diverse U.S. Populations

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Over one billion individuals globally suffer from mental disorders, encompassing a spectrum of neurological conditions that affect interactions, communication, learning, and behavior. Genetic predisposition plays a crucial role in the development of these conditions. Notably, genetic variants in the protocadherin (PCDH) gene cluster have been implicated in neurodevelopmental and neuropsychiatric disorders, including Autism Spectrum Disorder (ASD). The PCDH gene cluster is essential for the proper formation of neural circuits during early development, with its stochastic expression generating unique molecular barcodes on neuron surfaces to ensure accurate neuron self-identification. Previous studies have demonstrated that the deletion of PCDHαc2 in mice results in the clumping of serotonergic neurons, underscoring the importance of PCDHαc2 in neuronal self-avoidance. Restoration of the wildtype PCDHαc2 isoform in these neurons reestablishes proper serotonergic projections. Our research investigates the impact of two single nucleotide variants in PCDHαc2 on neuron self-avoidance and serotonergic tiling. The first variant, PCDHαc2(D249V), identified in an individual with ASD, and the second variant, PCDHαc2(M435R), which disrupts the interaction interface between PCDH proteins, are both predicted to impair PCDH function. To elucidate the functional implications of these variants, we employed lentivirus and adeno-associated virus (AAV) vectors to express both wildtype and mutant PCDHαc2 isoforms in primary cortical neurons derived from PCDHαc2 deletion mice. This approach aims to determine whether each PCDHαc2 isoform can restore proper self-avoidance and serotonergic tiling. We will then leverage computational models developed in R to analyze genome profiles specifically focusing on PCDH gene variants. By utilizing national and Mount Sinai genomic cohorts, we will assess the effects of these PCDH variants on neural cellular structures. Additionally, we will employ AI to analyze genetic datasets from the All of Us Research database to identify carriers of these PCDH variants, providing a comprehensive understanding of their prevalence and potential impact on neurodevelopmental disorders. These results will offer critical insights into how sequence variants in PCDH genes contribute to neurodevelopmental disorders, potentially leading to novel treatment strategies. Our research aspires to bridge the gap between genetic mutations and clinical manifestations, ultimately contributing to the development of precision medicine approaches for mental health disorders.

Enhancing Generalization and Accuracy in Predicting Days of Maintenance Delay for U.S. Navy Ships

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The Big Data Analytics Laboratory, in conjunction with the Office of Naval Research, is working on a critical project that addresses a growing concern of the United States Navy. Systematically, there is a high frequency of ship maintenance delays, significantly impacting them both financially and operationally.

Problematically, from 2015 to 2019, about 75% of ships tasked for maintenance have been significantly delayed (CRS 2021). This has also decreased ships' hours at sea, even though an additional 33 ships were added to the Navy since 2011. Furthermore, unplanned ship delays also levy a significant financial burden on the United States Navy, amounting to over 1.2 billion dollars (Shkolnikova 2023). With the Navy's "North Star 75" strategy – always having 75 surface vessels mission-ready, an urgent solution to manage this delay is required.

To combat this, the Predictive Analytics for Ship Scheduling project (PASS) under the Big Data Analytics Laboratory aims to design a robust machine learning pipeline that will predict maintenance delays. Because this is an extensive, almost three year long, project, my role includes investigating overfitting, while aiding in increasing the model's generalization to unseen data. (when the model is overly trained on one data set, thus resulting in low performance for other data sets). To evaluate the problem, the team is aiming to reduce the following success metrics:

$$success\ metric\ =\ weight_{overfitting}\ *\ (residuals_{test} + residuals_{val})\ +\ weight_{performance}\ *\ MAE_{overall}$$

With:

- $weight_{overfitting} = 0.15$
- $weight_{performance} = 0.7$

To reduce overall MAE, my first task will be to investigate different reduction methods that aim to smooth the prediction of delays at different steps of the pipeline for each vessel. Investigating different reduction methods will allow us to obtain higher accuracy predictions, without having to significantly alter the machine learning pipeline. This reduction method study is an introduction to the machine learning pipeline that focuses on the model evaluation module. It will provide insightful leads in finding ways to reduce overfitting by implementing research-based solutions within the model training module.

What is the Impact of Visual Clutter on Emotion Recognition in Video Conferencing?

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Abstract: The human visual system is very good at getting the essence of scenes within milliseconds. Similarly, we can perceive the perceptual averages of various features of visual stimuli such as the mean size of groups of items, the average speed of moving objects, or the average emotion of a crowd, effortlessly. This ability to compute summary statistics of visual stimuli is also known as ensemble perception. Ensemble perception research has traditionally focused on controlled stimuli, but it is also crucial to test its applicability to real-life stimuli. Here, video conferencing displays offer a significant use case, especially given the pandemic-driven surge in video conferencing tool usage. Additionally, there is a need for clear communication between the presenter and the audience especially since it is hard to understand emotion through a screen as opposed to an in-person audience. This project examines the effect of visual complexity on ensemble perception during video conferencing. We hope to demonstrate how well people can recognize the average emotion of a group of individuals in a video conferencing setting. We will create visual stimuli resembling video conferencing displays with faces superimposed on virtual backgrounds. Furthermore, we will manipulate the number of attendees (set size), background complexity, visual eccentricity (e.g., the distance between the gaze point and the stimulus location), emotional valence, and intensity of virtual attendees in virtual meetings. Furthermore, we will measure emotion recognition performance in an eye-tracking set-up. We hypothesize performance to decrease with increasing set size, background complexity, saliency, and visual eccentricity. Our research project has significant implications for better designs to improve the video conferencing experience and have more emotionally engaging video calls.

Immersive Design: Amplifying User Learning with Gamification in VR

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Abstract: Virtual Reality (VR) is an emerging area of interest for the field of education and public engagement, yet its scope and effectiveness vary widely. VR shows great potential for higher engagement and immersion with information presented in digital space. From the project, *Hidden in Plain Sight: Reconstructing Lost Histories in Istanbul and Rome*, VR has been used to create an "interactive narrative framework," allowing for the annotation of physical and digital spaces to teach about the history of an area through digital storytelling and historical reconstruction. This project aims to explore and define specific methods and elements of a VR environment that will improve the user's navigation of the experience and assist in the retention of information. Previous work on the contribution of VR to a user's immersion is inconsistent, with different applications succeeding or failing to reliably benefit the user's experience. This project intends to utilize gamification, applying elements from games into a non-gaming and scholarly context, in an attempt to facilitate user learning for the wider public. By defining methods to guide a user through an experience using 3D models and 360 images, user interfaces, environments, and visual and auditory stimuli, the project intends to increase user engagement with the presented material. This will extend the interactive narrative framework to more efficiently guide the user through the space, and direct user attention more naturally, so that their exploration is intrinsic. In the future, this project will utilize its developed features to test users and discover what elements improve the user's engagement most effectively. The use of VR for educational purposes has great interdisciplinary potential, meaning that effectiveness in its design through gamification would allow for significant improvements in the transfer of knowledge within its medium.

Fine Tuning Large Language Models for Increased Prediction Accuracy in Time Series Forecasting

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Time series forecasting is essential for predicting future outcomes in dynamic systems such as weather patterns, stock markets, and traffic flows. Traditional models require specific designs for each application, presenting challenges in flexibility and scalability. This research introduces TIME-LLM, a novel reprogramming framework that transforms time series data into text prototypes, aligning it with the capabilities of large language models (LLMs). By keeping the backbone LLM intact and employing the Prompt-as-Prefix (PaP) technique, which enriches input data with declarative prompts, TIME-LLM leverages the pattern recognition and reasoning strengths of LLMs to generate accurate forecasts without extensive retraining.

We predict that the accuracy of time series forecasting can be significantly increased by fine-tuning the parameters of the models we are using. By increasing the time-step for each respective model trained, we predict that the prediction accuracy will increase. Another factor that could possibly increase predictive capabilities is the batch size for training the models. This adaptability is crucial for enhancing forecasting performance across various domains.

TIME-LLM offers significant advantages for industries such as finance, healthcare, energy, and retail. Its effectiveness in few-shot and zero-shot learning scenarios makes it valuable for situations with limited historical data, reducing the need for domain-specific model development. Moreover, TIME-LLM's enhanced accuracy and robustness can lead to substantial operational efficiencies and cost savings, particularly in supply chain management, inventory optimization, and energy load forecasting.

In summary, TIME-LLM represents a transformative advancement in time series forecasting. It provides an adaptable, efficient, and powerful tool that paves the way for intelligent and integrated forecasting systems capable of handling diverse and complex data with minimal customization. This research significantly enhances forecasting capabilities in real-world applications, offering a versatile solution for improving forecasting accuracy and operational decision-making across various sectors.

Teaching Virtual Reality Gestures for Easier Player Integration

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Virtual reality is an emerging technology with various applications for future interaction and engagement. This research project aims to study how non-gaming users of virtual reality interact with the medium and how quickly they can learn and pick up virtual reality concepts. Understanding the methods by which people learn will give virtual reality developers insight into integrating new users and expanding virtual reality's market reach. The experiment will aim to test two main training methods: pre- and during game training. The participants will be assigned two sets of three gestures (six total) and perform one set of gestures in pre-training and one in the main game. In pre-training, the participants will have time to practice before they are launched into the main game and have to defeat enemies, whilst during game training the participants must learn the gestures as they play, creating pressure as the enemies creep closer. Of the six gestures, two require one hand to move, two require both hands to move symmetrically, and two require both hands to move asymmetrically. Each set of gestures will have one of each type, and the order in which they are taught will be randomized. Participants will be given different variations of these gesture sets in comparison to other participants with the goal of gathering data about each gesture in a variety of environments. Participants will play the game through a head-mounted display (HMD), and after putting on the HMD, they will proceed through a series of in-game scenes. Participants will start in pre-training and learn set one, move on to the main game (with enemies), move on to main game training and learn set two, take a break by removing the HMD, and finally return to an empty play area and perform the gestures they learned in a recall portion of the game without aid. The anticipated results of the experiment will be that gestures learned in pre-training will be better remembered by participants and that they will have an easier time learning and using those gestures. This is because participants not used to virtual reality may require extra time to get acquainted with the technology before being thrown into the main game. The more relaxed atmosphere of the pre-training module will also give participants time to be confident rather than executing gestures through blind guessing. Ways to build off of this research will be to add gestures with leg tracking, run a series of experiments to test different control groups, and learn how to integrate visually and physically impaired participants who were excluded from the participant pool. In the future, virtual reality could be integrated into a vast array of environments such as nursing homes or the classroom. This has already been seen, and with further research, virtual reality will have a market in something more than just games.

Solving Fast Fair Bandit with Switching Cost Using Reinforcement Learning

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Abstract: The multi-armed bandit (MAB) problem where different arms correspond to different rewards (unknown) is becoming widely popular. In many applications, ranging from wireless to recommendation systems, MAB is used. In this project, we consider the traditional MAB problem with two additional challenges– **i) satisfying constraints, and ii) incurring costs for switching arms**. In particular, in addition to getting a reward for drawing an arm, there is a switching cost in switching arms between two-time slots; further, one needs to ensure that the fairness constraint is maintained at each time slot. Such constraints are prevalent in practice. Considering the example of a recommendation system, to maintain fairness one needs to ensure that the contents from diverse groups should appear with non-zero probability. Similarly, if one wants to change the beam directions (Arms) in mmWave communication or the contents (Arms) in the recommender system, it might incur a significant cost. Traditional MAB approaches require frequent switching of arms for efficient exploration and are not equipped to satisfy constraints. While algorithms have been proposed to solve this problem, theoretical and practical performances are sub-optimal. We thus, propose a Reinforcement-Learning (RL) based approach to solve this problem. In particular, because of the advancement of the RL in solving complex engineering problems, we, thus, envision that the RL algorithm can have a better theoretical and empirical performance. **Such a development will be significant and impactful in applying ML-based tools for many applications such as edge devices, wireless communication, and recommender systems.**

Navigating by Nature: Harnessing Birdsong for Spatial Perception

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Abstract: Birdsong has the potential to convey a wealth of information regarding the bird's environment, including the location of territorial boundaries among birds and the presence of danger. However, they may also provide valuable information for spatial perception and localization, which is crucial in the field of robotics. In our research, we aim to investigate how changes in frequency over time during birdsong can be used to accurately calculate distance to an object located between the source and the listener. This research takes on an interdisciplinary approach through collaboration between Drs. Swissler and Hyland-Bruno; Our work has implications not only in the robotics field by introducing a cheap method of localization for large-scale robot swarms, but also in providing a deeper understanding of how birds perceive and interpret their environments based on birdsong. To accomplish this, I sought to optimize and expand upon an existing MATLAB simulation created by Dr. Swissler as a proof of concept. The program has the ability to plot time as a function of the observed frequencies of a pre-recorded bird call using simulated microphones and speakers (Figure 1). This allows us to calculate an estimated distance to an obstacle located between the source and the listener by using the difference in time at which a given frequency is observed. Moreover, this will lead to future research to continue developing the model to map an environment entirely based on the varying frequencies of birdsong.

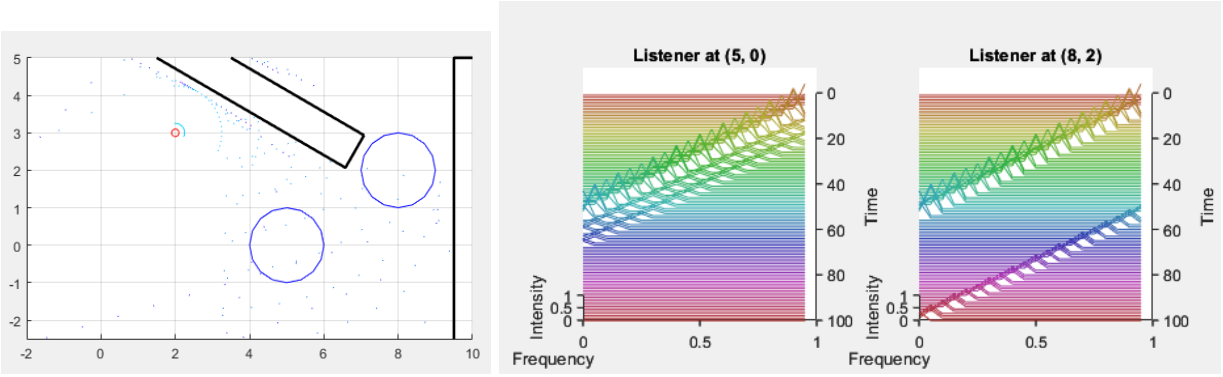

Figure 1: On the left is a room simulation with a speaker, represented by the red circle, and microphones, represented by the blue circles. The black rectangles represent walls within the environment that we want to estimate a microphone's distance from. On the right are the resulting plots generated from the MATLAB program, which will be used to obtain the data necessary for calculating estimated distances between a listener and an object.

Autonomous Robot Self Assembly Inspired by Slime Mold Growths

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Self-assembly is a behavior utilized by various small organisms where they come together in a large group in order to adapt to various environments. This phenomenon can be seen in insect colonies, bacteria colonies, and slime molds, where individual entities interact based on simple rules, resulting in complex group behaviors and self-organized structure. Slime molds in particular are single celled organisms that are able collectively identify nearby food sources and create optimal networks to transfer nutrients and information. If this kind of behavior can be replicated within robotics, then robot swarms could be deployed in unsafe environments, instead of human workers to survey the surrounding and create emergency structures. The objective of this research is to replicate this self-assembly behavior using a novel slime-mold inspired self-assembly algorithm which can eventually be implemented on real-world robots. This algorithm, which will be programmed in MATLAB, will enable robot cubes to climb and build off each other to autonomously create structures and reach previously unreachable positions. Unlike other robot self-assembly systems, each individual robot cell is decentralized and can only utilize local forces and communications in order to influence the growth of the structure, which mimics the capabilities of a single slime-mold cell. Along with developing the algorithm, a simulation will also be created to evaluate the algorithm. By the completion of this project, the algorithm and simulation will be developed enough for it to be implemented into physical robots.

A Statistical Analysis of Student Voice Trends in NJIT's The Vector

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College newspapers have been the subject of much inquiry, which can allow for a better understanding of student voice. 17 issues of NJIT's The Vector were collected, between the years 1931 and 2024, and each issue was analyzed for trends. Due to the low barrier of entry, the Vector is likely a good indication of the beliefs of all students. The number of writers has been shown, with 99% confidence using a Linear Regression T Test, to be growing from 1931 to 1994, correlating with NJIT's growth. The number of writers stagnated from 1994 to 2024. This may arise from NJIT shifting focus from writing skills to computer skills, or from the internet becoming the new place to discuss important issues. A Paired T Test shows with 90% confidence that NJIT favors New Jersey issues over New York ones, even when excluding campus and Newark issues. One reason was more importance placed on legislation in Trenton than commerce in New York. In addition, NJIT looks to New Jersey for culture rather than New York. With 85% confidence, a Linear Regression T Tests reveals a significant decline in campus issues and a growth in local issues, with local referring to everything within 15 miles of NJIT excluding the campus. Campus issues always remain the most represented, due to the fact that a college newspaper's purpose is to act as a place for discussions of the college community and student life issues. The decrease in campus representation indicates NJIT's growing interest in Newark. The perception of Newark does not seem to be related to any major Newark historical events as no change in the trend is present after the 1967 rebellion or 1997 opening of NJPAC, both considered turning points in Newark history. This indicates the apolitical nature of NJIT, likely due to the lack of training NJIT students receive in political writing. This trend also shows that NJIT's 1972 commitment to bettering Newark was a strengthening of old beliefs. The best way to improve NJIT using this research is to promote programs that allow students to help Newark in a visible way and the students' ability to promote their beliefs through writing. Future research should involve expanding the sample size of this study to confirm the strength of the trends.

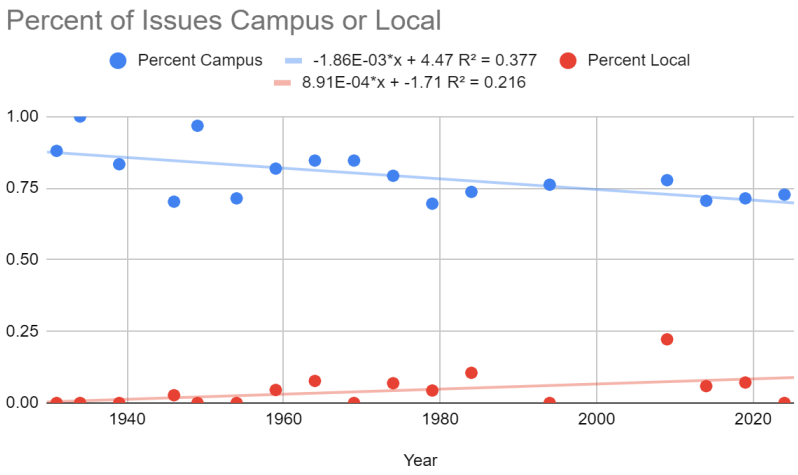

Figure 1: Graph showing the trend in campus or local issues

Usability Evaluation of Multi-User Virtual Reality Ontology Object Manipulation (VROOM)

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Ontologies are repositories of knowledge that encapsulate terms within a specific domain and the relationships between them. When visualized as a graph, each node represents a concept, and links express a binary relationship between pairs of concepts. Such a network can have thousands of nodes, making visualization and manipulation highly complex. To address this issue, Dr. James Geller and Dr. Margarita Vinnikov developed Virtual Reality Ontology Object Manipulation (VROOM), a system enabling users to browse and interact with a large-scale ontology in a virtual three-dimensional space. Our prior usability study on the single-user version of VROOM indicated higher user satisfaction and engagement than two-dimensional displays. Building on these findings, our study aims to explore the collaborative aspects of ontology visualization and manipulation within VROOM, recognizing the inherently collaborative nature of ontology development. Our research methodology involves a between-subjects usability study in which participants interact with a large-scale ontology in either single-user or multi-user VR settings. Participants are given a set of visualization and authoring tasks that they must work together to complete, and their performance is evaluated quantitatively and qualitatively. We expect this approach to enhance our understanding of our system's usability and shed light on user behavior and group dynamics during collaboration in an immersive virtual setting. Based on the insights gained from this research, future work will focus on refining VROOM's multi-user capabilities to improve the collaborative ontology development processes in virtual reality.

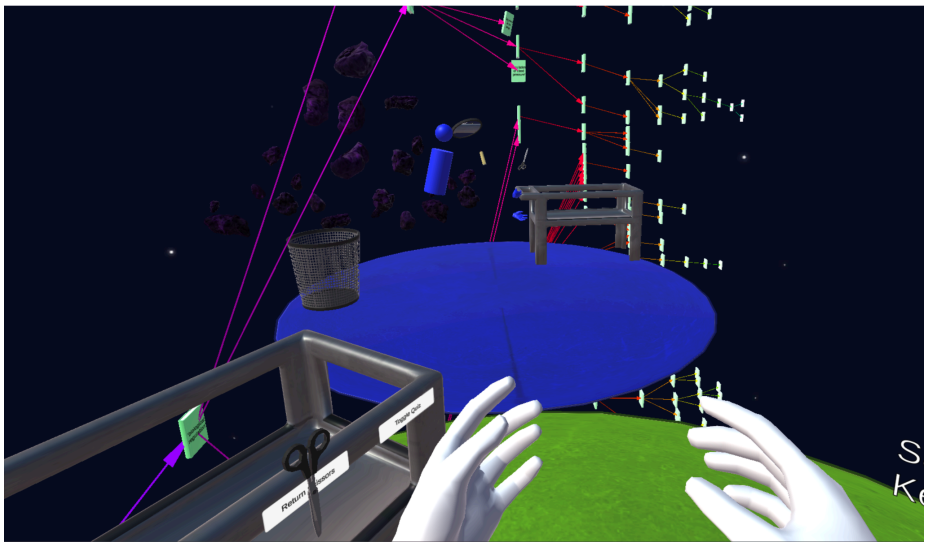

Fig. 1: Headset view of multiple players interacting with the ontology in virtual reality.

Determining if the HCS Independence Finding Holds at Higher Latitudes

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Abstract: Small scale magnetic flux ropes (SMFRs) are a category of magnetic flux ropes (MFRs) that are difficult to detect yet are very abundant in the solar system. Not much is known about their structure or behavior however there are some patterns they follow. One such pattern is the clustering principle, an observation that SMFRs tend to cluster around the heliospheric current sheet (HCS). However, after a more efficient detection algorithm was developed, it was discovered that many previous conclusions about SMFRs may have been a product of statistical bias. It was shown by Farooki et al. (2024) that the clustering principle at low latitudes is one such conclusion. The spacecraft measuring the data detects more around the HCS which produces the artificial result that SMFRs cluster around the HCS. This study aims to use the improved detection algorithm to find if the HCS independence finding is consistent at higher latitudes. Data on their distribution with respect to latitude and longitude will be analyzed to find out how they are distributed within the heliosphere and how they interact with their surroundings if at all. While this paper will focus mainly on the clustering of SMFRs, the ultimate aim of this paper is to explore their nature and behavior and to further understand the interactions between them and other objects in the solar system. Understanding SMFRs, which are abundant within the solar system, is important for the understanding of the solar system as a whole and the different dynamics that occur within.

Navigating the Uncanny Valley: Optimizing VR Training Character Design

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In the realm of virtual reality (VR) training, the optimal design of digital characters is a subject of ongoing debate. Although significant advances have been made in VR technology, there is still no consensus on whether hyper-realistic or stylized characters are more effective in training simulations. Immersion is a crucial factor in a VR experience, but without a balance in functionality, the effectiveness of a simulator becomes questionable. This project aims to compare hyper-realistic, "stylized-realistic," and stylized characters in VR training. Using 3D software and motion capture technology, we will assess the immersiveness of these different character designs.

Our study utilizes Character Creator, iClone, MVN Xsens for body motion capture, and LIVE Face for facial capture. By creating a series of natural movements that can be attached to an AI interface with aim to enable non-playable characters (NPCs) to interact with the player in various ways. The AI, powered by CONVAI, will allow NPCs to respond contextually, making them versatile for professional training and general interactivity within the VR world. The objective is to determine which character design provides the highest level of immersion, thereby enhancing the effectiveness of VR training simulations.

The concept of the Uncanny Valley, introduced by Masahiro Mori in 1970, will be a central consideration in our analysis. This phenomenon describes how human-like robots can evoke feelings of familiarity or unease. By investigating the balance between realism and stylization, we aim to provide insights into the optimal character design for immersive VR training.

Our experimental design includes the development of various character models and their integration into VR scenarios. We will conduct user studies to evaluate the perceived immersion and effectiveness of each character design. Our findings will highlight the importance of character design in VR training and contribute to the ongoing discourse on immersive technology in education and training as well as aim to create an established process that may be followed for the development of future VR interactivity simulators.

Future work will focus on refining the character designs based on user feedback and exploring their applications in different training contexts. By addressing the Uncanny Valley and optimizing character interactions, this research aims to enhance the overall VR training experience.

Self-Assembly of Transport Tile Robotic System for Flood Response

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Abstract: Self-assembling swarm robotics allow a network of robots to tackle environmental challenges such as transportation in rough terrain or going through obstacles. However, most successful systems are done at a much smaller scale. Transport Tiles are built for jobs that require carrying large and heavy objects.The tiles are meant to work in unison in order to carry palettes loaded with heavy objects such as bricks. This type of system provides a safer alternative for transporting building materials and equipment through terrain that would be otherwise dangerous for humans to go through. These Transport Tiles must be able to hold their own weight so that they can assemble themselves. The linear actuator powering the rotating arm must be able to lift the robot's weight. A conveyor belt is made up of six wheels powered by a motor whose motion is transmitted through a roller chain. These wheels have to move other robots, heavy materials, and other equipment without any strain on the wheels, chain, or motor. The whole top frame of the robot must be able to rotate a full 360 degrees. The six faces of the robot must be able to dock onto another face, to establish a secure connection within the system. From experiments conducted in the lab, we found that the robot succeeds in all its functions. The linear actuator that powers the arm does not struggle supporting the weight of another robot. The conveyor belt handles the weight of the palette and moves it as it is meant to. The docking mechanism on each face of the robot works properly with other robots. The robots are able to lift their own weight and assemble themselves. All the physical mechanisms work as intended, with little to no stress on any moving component. We conclude that self-assembly is possible with this robot system and we can move forward with the programming to make these robots autonomous. That way the swarm of robots can assemble themselves without any human help.

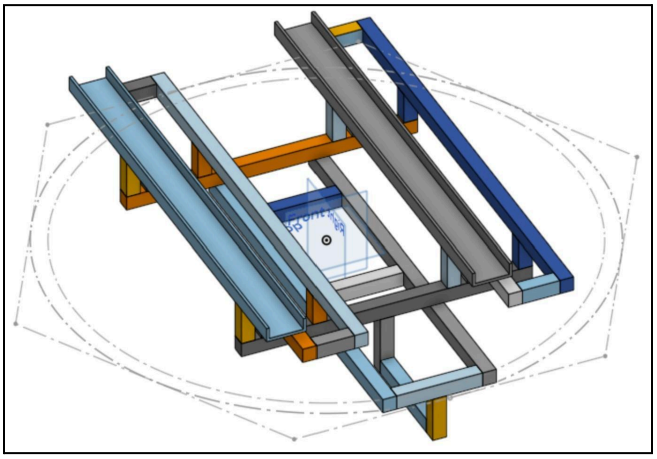

Figure 1. Top Frame of Robot

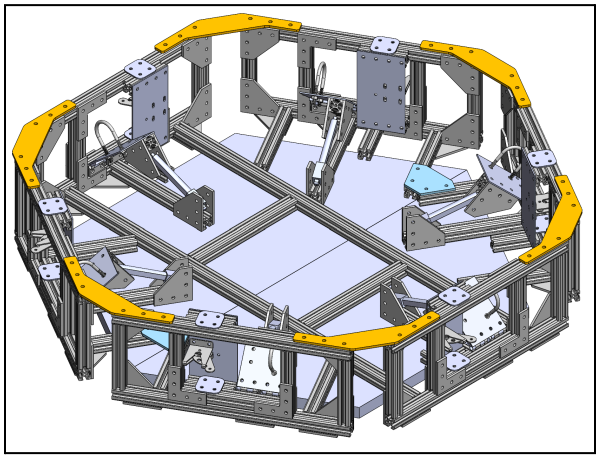

Figure 2. Bottom Frame of Robot

Quantifying Global Learning: A Data-Driven Analysis and Visualization of the Study Abroad Experience

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Abstract: While study abroad is largely considered an excellent experiential learning opportunity, the benefits can vary from program to program. This research project aims to assess the impact of the NJIT study abroad programs, through the areas of career readiness and cultural competence, using a comparative analysis against national study abroad programs. Data will be collected from NJIT offices and participants via surveys and compared to existing research conducted on a national level to identify trends and draw conclusions. The data collected will be displayed on a custom interactive dashboard for the Office of Global Initiatives, incorporating an LLM-backed algorithm for analysis and a continuous data integration system, to monitor the study abroad programs improvement over time. The dashboard aims to provide NJIT administrators with actionable insights, supporting data-driven decisions to tailor the programs to NJIT students and ultimately increase experiential learning participation amongst NJIT scholars. The NJIT data is currently inaccessible, but future plans for the research project involve transferring it to the Office of Global Initiatives. They will integrate the correct data into the algorithm I have already implemented and tested using stub data, ensuring it is fully operational and ready for deployment.

Machine Learning Models to Predict Cholera Infection in an Ottoman Asylum

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Abstract: Cholera outbreaks played a significant role in shaping medical practices in medical institutions, particularly during the nineteenth and early twentieth centuries when the world was hit by six major cholera epidemics. Cholera is a disease that primarily spreads through water contaminated with the *Vibrio cholerae* bacteria and historically, it posed a greater threat to regulated environments such as psychiatric institutions. This project builds upon my previous project which involved modeling spatial and functional changes brought about by cholera outbreaks in an agent-based model (ABM) of Toptaşi Asylum (1873-1924), a key mental asylum in the Ottoman Empire. An ABM is a computational model of autonomous individuals, called agents, that interact with each other and their environment. The ABM of Toptaşi Asylum contains agents that represent various classes of asylum inhabitants (patient, caretaker, doctor, etc.), each with set schedules determined by natural language files. This project focuses on applying machine learning techniques to accurately classify agents as being cholera-infected or not in our ABM. We will run the simulation of the asylum several times to construct a dataset of features that may contribute to the spread of cholera, selected by conducting further research, such as the time the agents spend in the dining hall or the restrooms (common spaces of contagion). Then, using this dataset, we will train several machine-learning models that predict which agents in the ABM should be classified as infected. These predictions will then be compared to historical data available about the number of cases throughout the outbreaks from August 29, 1893 to October 5, 1893, which will then be used to inform decisions about optimizing our models. We will also create data visualizations that map the correlation between the features of the dataset and the cholera classifications to interpret the results. This research project will help us better understand the factors that influenced cholera to spread in Toptaşi Asylum. More generally, it may demonstrate the utility of machine learning integrated with agent-based modeling to analyze infectious diseases in highly regulated environments.

Creating a Multi-User Virtual Reality System for Ontology Visualizations

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Ontologies are networks consisting of terms in a specific domain and their relationships. These are represented as graphs and allow for quickly finding any given term by traversing its related terms. These ontologies are helpful because they provide unified collections of concepts that scholars of the domain can discuss and apply to their work. Many ontologies are visualized in two dimensions, but they can become quite large, complex, and hard to visualize when there are millions of terms and connections. For this reason, the Virtual Reality Ontology Object Manipulation (VROOM) system was developed, which allows users to view an ontology in a three-dimensional virtual reality world. The user can use their headset and controllers to navigate around the ontology visualization in all three axes. VROOM has many tools and menus to help both novice and expert users analyze and modify the ontology, including a magnifying glass, a glue stick, and scissors. In a study evaluating the usability and effectiveness of VROOM, it was found that VROOM excelled in providing enjoyment to users and improving their ability to recall information. This version of VROOM only supported a single user, but this research aims to modify the program to support multiple users while improving usability compared to the previous study. VROOM is created in the Unity game engine, and the multiplayer functionality is provided by Unity's Netcode for GameObjects library. First, solutions must be developed for synchronizing player avatars and their movements, as well as the ontology and any changes made. In addition, some changes to the interface will be made to improve the user experience. Next, the usability and viability of the new VROOM system will be measured through a study in which groups of participants will complete tasks with the system. In the future, the new VROOM system will have an optimized multi-user experience that can handle collaboration in developing ontology visualizations.

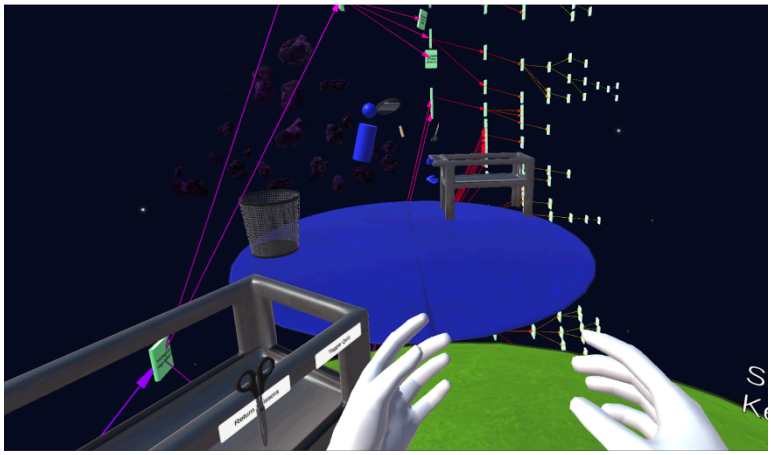

Figure 1: Headset view of multiple players interacting with the ontology in virtual reality.

Comparison of the dynamics of exoskeletal-assisted locomotion in an FDA-approved lower extremity device: Controlled experiments and development of a subject-specific virtual simulator

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Spinal cord injuries (SCI) have an annual occurrence of about 18,000 cases in the United States, resulting in partial or complete loss of sensory and motor function. Lower extremity exoskeletons are currently the only non-invasive way to restore independent, upright mobility for persons with SCI. However, substantial forces caused by human-robot interactions are brought to bear on lower limbs during exoskeletal-assisted walking (EAW), which may result in bone fracture for persons with SCI. Currently, little is known about the dynamics and joint loads associated with EAW for persons with SCI. Thus, the goal of this work is to quantify the human-robot dynamics and joint reaction forces (JRFs) of a person with SCI during EAW in three FDA-approved exoskeletons: ReWalk, Indego, and Ekso. We recruited one person with SCI to perform 3-D motion capture experiments at the NJIT Life Sciences Motion Capture Lab, where simultaneous measurements of marker trajectories, ground reaction forces, and robot motor torques were collected (Fig 1A). 3-D marker trajectories were processed in Vicon Nexus (Fig 1B) and used to scale a generic human model in OpenSim to match our participant's mass and body segment dimensions (Fig 1C). We will compute joint angles and moments at the hips, knees, and ankles using OpenSim's Inverse Kinematics (Fig 1D) and Inverse Dynamics (Fig 1E) tools, respectively. We will estimate JRF using muscle-driven simulations of EAW using OpenSim's extension, OpenSim Moco (Fig 1F). At the completion of this project, we expect to generate the joint angles, moments, and forces of a person with SCI performing EAW in the three FDA-approved exoskeletons.

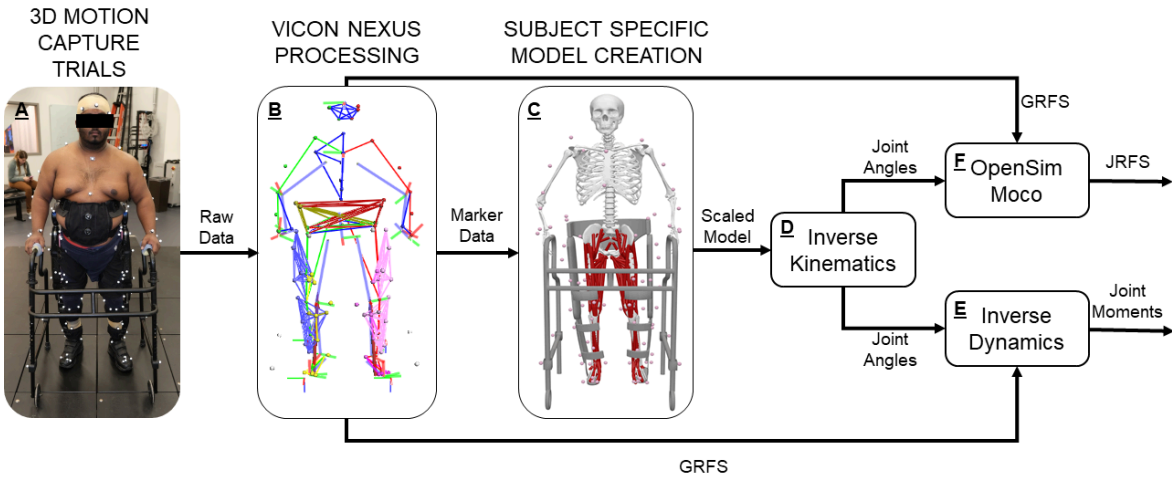

Figure 1: Flow Chart of Pipeline