NJIT
New Jersey Institute of Technology

BOOK OF ABSTRACTS

2022 UNDERGRADUATE SUMMER RESEARCH AND INNOVATION SYMPOSIUM

JULY 27-28, 2022

2022 Undergraduate Summer Research and Innovation Symposium

July 27-28, 2022

PROGRAM

Undergraduate Research and Innovation (URI)
Office of Research
New Jersey Institute of Technology

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Notes: *Team Project Presenters:* *1: Christopher Henni, Emad Sawages*

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Studying Amyloid Fibril Formation Using Computer Simulations

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Abstract: At high concentration, amyloid proteins aggregate and form fibrils, which are the hallmark of diseases like Alzheimer's and Parkinson's. Non-pathological proteins have also been found to form amyloid-like fibrils. Several of those proteins exert biological function in the cell while others are being explored for biotechnological applications including wound healing. The relationship between the peptide sequence and its propensity to aggregate into fibril structures is still not fully understood. The goal of my project is to explore this relationship using all-atom molecular dynamics simulation. The team used Gromacs software as the simulator, Chimera and VMD to visualize atomic structure, and the Lochness supercomputer cluster at the New Jersey Institute of technology in order to perform the all atom simulations.

During the summer, I explored 5 peptide sequences for their propensity to form fibrils. These peptides are amphipathic with sequence alternating between non-polar (either phenylalanine or alanine) and polar residues (either lysine or glutamic acid). My objective was to understand how replacing one phenylalanine residue in the peptide sequence with alanine affected the propensity of the peptide to form fibril. The sequences we explored were:

AKFEFKFE, FKAEFKFE, FKFEAKFE, FKFEFKAE, FKFEFKFE

Simulations were carried out successfully and a few of the amino acid sequences above formed fibrils. This is very promising. However, these results need to be reproduced. Moreover, it remains unclear how the position of alanine in the peptide sequence affects fibril formation. A more careful analysis of the results needs to be performed.

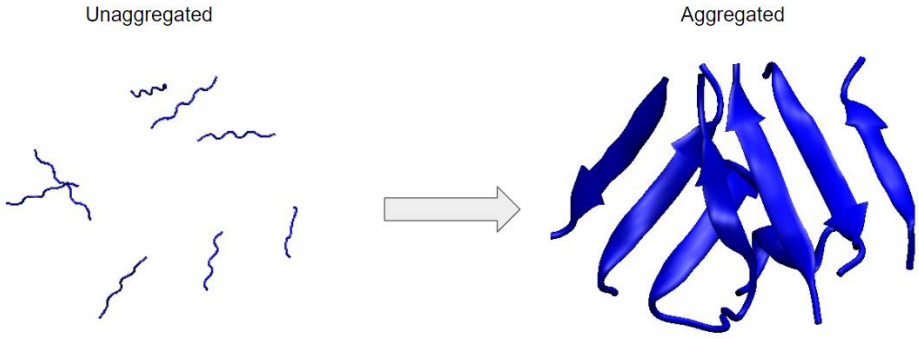

Figure 1

Point-Of-Care Clinical Device to Screen Microcystin-LR, Anatoxin-a, and Cylindrospermopsin Found in Freshwater

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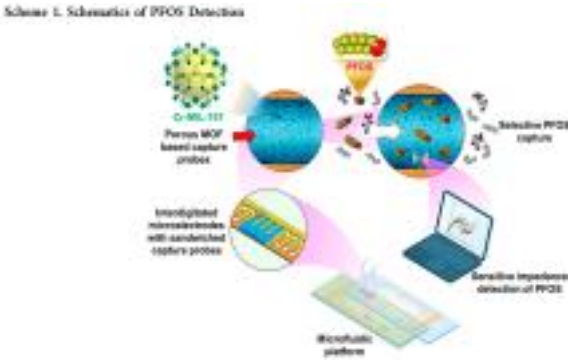
Abstract: The lack of portable devices to detect microtoxins in freshwater has encouraged researchers to improve a device that can save patients time, money, and possible health complications.Researchers at NJIT have developed a sensor platform, ESSENCE (Electrochemical Sensor that uses a Shear-Enhanced, flow-through Nanoporous Capacitive Electrode), to overcome electrochemical sensor limitations, specifically selectivity and sensitivity limitations. The creation of the device includes a microfluidic, affinity-based electrochemical sensor platform for rapid detection that offers unprecedented sensitivity through a combination of receptor probe design, electrode configuration, and their combination within the microfluidic lab-on-a-chip platform. The device consists of a microfluidic channel sandwiched between two sets of interdigitated microelectrodes. One microelectrode is packed with carbon-based transducer material such as carboxylated single-walled carbon nanotube, and another electrode acts as the reference electrode. The device also shifts signals to a higher frequency range, making the sensor very sensitive and rapid with a high signal-to-noise ratio. This study focused on three different microtoxins – Microcystins, Anatoxin-A, and Cylindrospermopsin in freshwater in 0.01, 0.1, 1, 10 ppb and redox probe pbs. Test runs consisted of three steps: Step 1 redox probe, Step 2 mictoxin and Step 3 redox probe. The results depended on the difference in Step 1 and Step 3. The results will be inputted into a Calibration Curve and analyzed for the three different microtoxins detection. It is concluded that results fall under the accurate and speedy diagnosis for the device. The results will either show a result of a microtoxin detection or not. Throughout the duration of the research, different ppbs in the microtoxins had detection, no detection or an assembling error resulting in peculiar graphs. The future work on the research project is an ongoing project with room for improvement and further investigating to help society.



Toxicity of Phthalate Mixture in Mouse Ovaries

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Abstract: Phthalates are a group of chemicals commonly used as plasticizers and solvents in various consumer products, personal care products, and medical equipment. The presence of phthalates and their metabolites in the human body indicate widespread exposure of humans to phthalates. Specifically, phthalates have been found to target the ovary. Thus, phthalate mixtures were investigated to determine their ovarian toxicity since humans are exposed to many phthalates simultaneously. The ovary is the source of female germ cells. It is responsible for the production of sex steroid hormones and the development of oocytes for fertilization. The goal of this project was to expose granulosa cells, the specific cells inside of the ovaries responsible for producing hormones, to mixtures of phthalates that represent human exposure to identify impacts on hormone levels. We hypothesized that if mouse ovaries are exposed to environmentally relevant phthalate mixtures, there will be a decrease in hormone levels in female mice. To test our hypothesis, granulosa cells harvested from adult female CD-1 mouse ovaries were cultured with either DMSO (vehicle control), phthalate mixture (0.1–100 μg/mL), or phthalate metabolite mixture (0.1–100 μg/mL). The phthalate mixture consisted of 35% diethyl phthalate, 21% di(2-ethylhexyl) phthalate, 15% dibutyl phthalate, 15% diisononyl phthalate, 8% diisobutyl phthalate, and 5% benzyl butyl phthalate. The phthalate metabolite mixture consisted of 37% monoethyl phthalate, 19% mono(2-ethylhexyl) phthalate, 15% monobutyl phthalate, 10% monoisononyl phthalate, 10% monoisobutyl phthalate, and 8% monobenzyl phthalate. After four days of culture, the culture media was subjected to enzyme-linked immunosorbent assays (ELISAs) to determine the concentration of the following hormones: progesterone, testosterone, estradiol, and androstenedione. We expect to find that environmentally relevant concentrations of the phthalate and metabolite mixtures cause a decrease in concentration of each hormone. This would suggest that phthalate mixtures are toxic to humans and may disrupt female fertility by altering hormone production.

Investigation of Capillary Blood Flow Dynamics in PMMA and PDMS Microchannel

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The controlled capillary flow of blood in microchannels under various hematocrit (volumetric concentration of red blood cells) conditions is essential to developing passive microfluidic devices. The hematocrit has a direct influence on capillary blood flow in the microchannel. However, the hematocrit range varies between each blood sample, with the human physiological hematocrit range being 36%-50%. To effectively apply the biochip technology, the capillary flow dynamics for the hematocrit range of whole blood need to be understood. The goals of this research project were to investigate the effect of changing hematocrit levels on capillary blood flow by comparing the blood drop contact angle on the surface and the blood flow rate in microchannels with two popular microchannel materials: polymethyl methacrylate (PMMA) and polydimethylsiloxane (PDMS). The PDMS microchannel was fabricated by curing a mixture of PDMS base and curing agent (10:1 ratio) on the Si master mold with 200 μm wide and 100 μm deep rectangular channel structures at 100 °C for 45 minutes. The PMMA microchannel was fabricated with CO_2 laser ablation with process parameters of 15 W laser power and 11.4 mm/s scanning speed at a resolution of 700 pulses per inch (PPI) to precisely reflect the dimensions of the PDMS microchannel. The microchannel surfaces were treated with oxygen plasma treatment for 90 seconds to increase the surface wettability and trigger a capillary flow inside the microchannels. The blood samples with 35%, 40%, 45%, and 50% hematocrit quantities were used to investigate the changes in the blood drop contact angle and flow rate in the microchannels. Increasing the hematocrit level from 35% to 50% showed: i) A trend of linear increase in blood drop contact angles on oxygen plasma treated PDMS and PMMA surfaces (90 seconds duration) from 31.9° to 45.4° and 26.7° to 35.0°, respectively. ii) A trend of linear decrease in blood flow velocity through 200 μm wide and 100 μm deep PDMS and PMMA microchannels from 22.6 mm/s to 9.5 mm/s and 10.1 mm/s to 3.3 mm/s, respectively. From the results, it is evident that with an increase in the hematocrit, the blood contact angle increases, and the flow rate through the microchannel decreases with both PDMS and PMMA materials. The achieved results under various hematocrit quantities using two popular microchannel materials are used to predict the capillary flow properties of blood flow in microfluidic devices. Future work consists of making improvements to the fabricated PMMA microchannel and further analyzing the blood flow dynamics inside microchannels of different cross-sectional shapes and dimensions using PDMS and PMMA materials.

Apply Physics Informed Neural Networks on Building a Superparamagnetic Nanoparticle Motion Model in Blood Vessels

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Abstract: Physics-informed Neural Networks (PINNs) are a branch of computing science that utilize Neural Networking under governing of physical equations. The high accuracy of PINNs' simulation results attracts researchers from different fields. Various researches test the limit of PINNs and all of them get very high accuracy in estimation of mathematical models, especially dynamic fluid field. On the other hand, to improve the magnetic drug delivery for disease treatment, a study of superparamagnetic nanoparticle motion in blood vessels in 2021 explores the relationships between various factors and their target results. It derives models from classical mathematical models such as Carreau Flow, magnetic field, and equation of motion. It is concluded that the distance from the magnet to the vessel impacts the most in the delivery. However, the simulation requires a long time to run throughout equations to get the result and cannot be reuse again.

As a different approach, the goal of this study is implementing the PINNs on the pre-established mathematical model of nanoparticle motion in blood vessels for magnetic drug delivery. In this research we studied the stochastic differential equation method in the blood flow and the usage of PINNs. Our research methods is 1) run the basic pure-data driven neural network code to understand each parameters; 2) implement a PINNs to run the model training under the preset stochastic equations. Our experimental design is setting up a basic PINNs code in Tensorflow API using the stochastic PDE as the loss function to guide the PINNs. The gradient of the loss function helps to improve and to relax the model. Comparing the result of pure data-driven Neural Networks and PINNs, it is observed that PINNs is much effective and faster to achieve a low loss under 2e-5. We also obtain a saved model with can be loaded and predict data without the need to train everytime.

As a conclusion, PINNs shows a new way to solve the complicate PDE problem and gives a new idea to combine the state-of-art neural network concept with classical physical models. With the guidance of physical equations, it shows a For future study, I suggest to implement more physics and fluid related PDEs to improve the PINNs design.

Exploring the Impact of Traumatic Brain Injury on Functional Brain Connectivity Using fMRI Data

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Traumatic brain injury (TBI) is a leading cause of death and disability in the US that causes about 52,000 deaths every year. Despite its prevalence the mechanisms of TBI are still misunderstood, making prevention and treatment challenging and even the best therapeutic strategies are unable to entirely treat it. Through this summer research project, I hope to gain a clearer understanding of how TBI affects the nervous system by creating and analyzing brain activity maps.

To explore the effects of TBI, Functional Magnetic Resonance Imaging (fMRI) data was utilized. fMRI is a neuroimaging technique that takes advantage of the magnetic properties of blood brain oxygenation to produce images of the brain. The changes in blood oxygenation are recieved through the fMRI machine as the BOLD (blood-oxygen-level-dependent) signal, which allows researchers to measure which regions of the brain are in a state of high activity. For this project I utilized anitomical and functional fMRI data from 32 healthy control and 20 mTBI subjects.

Preprocessing was conducted to prepare the data for analysis. This was accomplished using the MATLAB software, Statistical Parametric Mapping Version 12 (SPM 12). The goals of preprocessing were to remove unwanted artifacts such as head motion, transform the data into a standard format, and increase the signal that we are interested in.

After preprocessing was complete, group independent component (ICA) analysis was conducted using SPM's GIFT (Group ICA Of fMRI Toolbox) toolbox. Through ICA, we were able to decompose the brain into different components that allows us to see to what degree each component contributes to the observed signal and visualize altered functional connectivity in each component. Next, a 2 Sample T-Test was conducted to identify and compare significant differences between independent components in the controls and TBI patients.

Through ICA analysis I was able to identify brain networks affected by TBI. In all these regions, it was noted that subjects with TBI had significantly disrupted symmetrical connectivity. There was a significant decrease in connectivity in the salience (SAL) network which is responsible for determining which stimuli are important and deserving of our attention. I also noticed there was increased connectivity in the right anterior insula in the default mode network (DMN) network which is responsible for our mental-state processes at rest. My hypothesis is that this could be a compensatory mechanism among TBI patients. Because there is a disrupted ability to properly detect relevant stimuli, the increased connectivity in the DMN may be necessary in these patients to prevent interference of their ability to make goal-oriented choices.

These results provide us with a visual representation of networks affected by Traumatic Brain Injury. Furthermore, this will provide clinical researchers with a better understanding of how we can use fMRI to measure neural activity changes in other brain conditions. Future research can look at new significance levels and the effects of other factors such as gender or age.

Visual Colorimetric Detection of COVID-19 in Artificial Saliva Using Polydiacetylene Based Paper Biosensor

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Abstract:
Coronavirus (COVID-19) is an acute respiratory disease caused by Sars-Cov-2, which has led to millions of deaths and counting worldwide. The search and development of accurate and preferably rapid methods of detection is essential in treating and ceasing the spread of COVID-19. At the moment, the COVID-19 testing devices available include PCR tests and rapid tests. PCR tests can be tedious and uncomfortable whereas the current available rapid tests are not always accurate and can display false test results. Thus, the goal of this project was to produce a polydiacetylene based biosensor that can rapidly detect the COVID-19 spike protein that would be found in saliva. For the sake of this project, artificial saliva was used to conduct the experiment. To initiate the experiment, a polymer (PCDA-NHS) was synthesized; a transfer membrane was soaked into a solution containing the polymer, then it was made to dry and afterwards incubated into a Sars-Cov-2 spike solution. The transfer membrane containing the polymer and spike protein was dissolved in the artificial saliva (PBS). For optimal results, three experimental groups with different antibody concentrations in PBS were produced. The three concentrations were 1μg/mL, 100ng/mL, and 1ng/ml. After the designated 4 hour incubation period, the transfer membrane displayed a color change of blue to red which indicated that the biosensor interacted with virus in the saliva. The results were analyzed by Fourier-Transform Infrared Spectroscopy (FTIR) and Proton Nuclear Magnetic Resonance (1H-NMR) spectra.

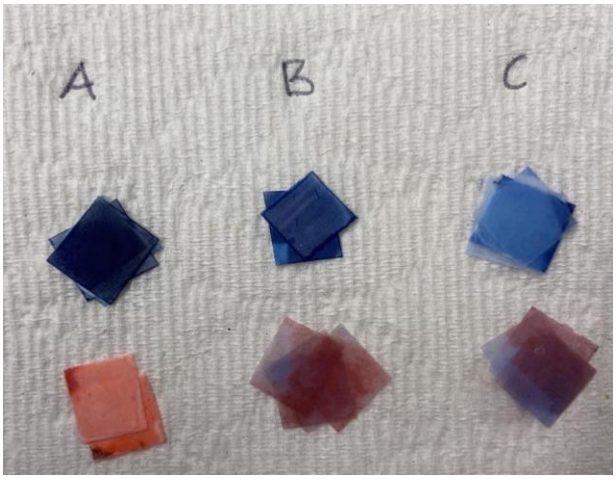

Figure 1: Image of transfer membrane color change from blue indicating negative for the presence of Sars-Cov-2 spike protein and red indicating a positive test result. Sample A, B, and C represent the different Sars-Cov-2 antibody concentrations, 1μg/mL, 100ng/mL, and 1ng/ml respectively.

Directed Enzyme Evolution

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Plastics have been produced in abundance over the past half century for a variety of industrial reasons. Many of the most desirable properties of plastics include durability, plasticity, and transparency. Plastics, mainly made of poly(ethylene terephthalate), are notorious for their persistence in the environment due to the lack of natural catabolic enzymes that can break them down into smaller parts. Poly(ethylene terephthalate), also known as PET, is resistant to microbial degradation because it has a high ratio of aromatic components and thus chemically inert. The mass production of plastics has raised alarms and has convinced many that a method of degradation is essential for the future of the environment.

In 2016, a bacterium that could degrade and assimilate PET was isolated and named *Ideonella sakaiensis*. The PET hydrolase (PETase) that was secreted by this bacterium to break down the PET resulted in the major bypropduct mono(2-hydroxyethyl) terephthalic acid (MHET) and minor products terephthalic acid (TPA) and bis(2-hydroxyethyl) TPA (BHET).

In our research, we plan to design and modify PET through a process called Directed Enzyme Evolution. Our research goal is to develop a screening technology that can assay mutant enzyme libraries to find a version of the PETase enzyme that will be more efficient in our goal of breaking down PET. We plan to achieve this by isolating and inducing mutations in the DNA segments that produce the PETase protein, allowing E.coli cells to express the protein, and then isolating single clones of in a plate and selecting higher activity clones to rescreen. An overview of this can be seen in Figure #1 below.

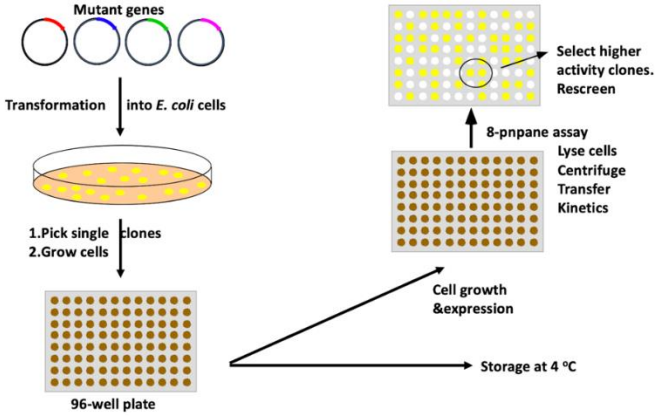

Figure 1: Overview of screening and selection

Most of my activities in the lab consisted of using gas chromatography, mass spectrometry, and liquid chromatography techniques to assess the reaction rates of our various samples. I had also created an SDS-page on induced and uninduced LCC (another PET-hydrolytic enzyme). We had spent much of our time with enzyme kinetic assays to assess whether our not our enzymes were still functional. By the end of the ten weeks, we were able to confirm, via enzyme kinetic assays, that the bacteria that were induced with the PET-hydrolytic proteins had consistently shown to have higher initial rates of product formation (such as Ethylene glycol) than the uninduced bacteria. This should have happened, because the cells that were induced should have produced more of the desired proteins. We learned that the uninduced cells had still shown some protein expression, but this could have been due to a leaky plasmid.

Overall, our results will help propel us to the next stages of research on PETase. After confirming that our enzymes are functioning properly, we will begin the screening and mutation processes that will ultimately provide us with a more efficient form of PETase.

Determining the Role of Cerebellum (Cb) to Substantia Nigra Pars Compacta (SNc) Projections in Conveying Movement Vigor

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Abstract: The cerebellum and the basal ganglia are distinct subcortical structures that are considered essential for the efficient, smooth, and coordinated execution of movement. Cerebellar ataxia and damage to the cerebellum (Cb) results in severe impairment of movement coordination, whereas degeneration dopamine neurons of the substantia nigra pars compacta (SNc) in the basal ganglia impairs the initiation and speed of movement. Both the Cb and SNc are considered learning systems in their own rights yet each is thought to contribute to the initiation and execution of movement through independent interactions with the cerebral cortex. The Cb constantly monitors the state of the body and the environment and corrects any movement errors, while the SNc contributes to the control of movement vigor: how long it takes the animal to act and how fast it moves. Recent studies, however, have reported a direct functional connection between these two structures. The output nuclei of the cerebellum send signals to the dopamine neurons of SNc (the Cb-SNc pathway) which carry reward value information and, when stimulated, appear to influence motor activity. Based on this information, we propose that the Cb-SNc pathway contributes to movement vigor through the rapid reward signals from the Cb to the SNc dopamine neurons. To examine this hypothesis, state of the art techniques including anatomical tracing methods with viruses, fiber photometry for calcium measurements and many more were used to ensure accurate and rigorous results. This study can represent a small step towards better understanding movement disorders and potentially developing therapies.

Electrospun Piezoelectric Nanofiber Device for Cancer Detection Using P(VDF-TrFE) fibers via Wearable Patch

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Abstract: The Center for Disease Control and Prevention reports that cancer is the second leading cause of death in the United States. More so, in 2020, over six hundred thousand Americans died from cancer. Invasive/minimally invasive methods are required to determine if a patient has cancer; why may be why cancers are not typically screened for during a routine doctor's visit. However, this leaves a gap in undiagnosed cancers. A wearable cancer detection device would enable easy detection, early onset diagnosis, and the ability to monitor patients during remission. Electrospun piezoelectric materials are readily used in biomedical engineering as they are biocompatible and can harvest electrical energy from mechanical energy, such as minute vibrations or frequency/amplitude changes from the patient. These electrospun piezoelectric nanofibers can be applied to cancer detection via a biosensor in which materials are layered together. This project layers polydimethylsiloxane (PDMS), carbon nanotube (CNT), polyvinylidene fluoride-trifluoroethylene P(VDF-TrFE) electrospun nanofibers, phosphate buffer solution (PBS), and a linker solution to fabricate a wearable device that has the potential to detect prostate cancer in the patients' blood. Piezoelectric material removes the need for a battery, resonator, or transducer, which makes the device less bulky, and more flexible/moldable to the patient. Also, this device would ensure that the live data would not be interrupted, such as a battery fail/replacement. Prostate cancer will be detected through prostate-specific antigen (PSA) antibody or α-fetoprotein antibody interaction with the PSA antigen. The biosensor will convey antibody-antigen interaction as a change in frequency and thus indicate the detection of carcinogenic antigens. Future work includes adding in the cancer detection layer of the wearable device to ensure accuracy and repeatability of detecting prostate cancer in the bloodstream. Also, continuous monitoring of PSA levels would be an added application to allow healthcare providers to see how prostate cancer responds to various drugs; thus, better knowledge to recommend a proven effective therapy. Once this device effectively detects prostate cancer, this technology can target other cancers such as lung, pancreatic, breast, etc. This introduction of wearable non-invasive piezoelectric biosensors, without a resonator or transducer, to detect carcinogenic biomarkers in the bloodstream would be a massive breakthrough in healthcare as wearable detection is far and few between and has yet to become widespread in the realm of oncology.

Inferring the Properties of Neuronal Synaptic Connectivity: A Combined Dynamic Modeling and Machine Learning Approach

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Experimental data often needs to be interpreted after data collection. For neuronal data, there is a scarcity in methodology to recover neuronal properties from experimentally collected data. This is especially a problem with degeneracies, which occur when multiple combinations of parameters can produce the same or similar outputs either biologically or mathematically. This is troublesome as the original properties or parameters may be hard, or even impossible to recover from just the observed data.

To tackle this issue, a combination of modeling and machine learning was employed. The model that was used was the so-called Lambda Omega model, a toy (caricature) model of neural oscillations and a canonical model for degeneracies. Time series data was generated numerically by using the Lambda-Omega Model. In this data, the ratio between the parameters lambda and beta was held constant, creating a mathematical degeneracy in the model for all combinations of these parameters having the same ratio. Gaussian white noise was introduced to the system to resolve the degeneracy. This time series data then had various features extracted (e.g, peak to peak distance) and was used as a training set for the machine learning algorithm. After being trained, it was able to predict an original parameter, lambda, from the various extracted features, with certain limitations in ranges of lambda.

In future work we will expand our study to include networks of lambda-omega models and oscillatory networks in general. Our results will contribute to the development of strategies to identify degeneracies in biological models, particularly neuronal models and to determine the causal vs. correlational relationships in synaptically connected neural networks.

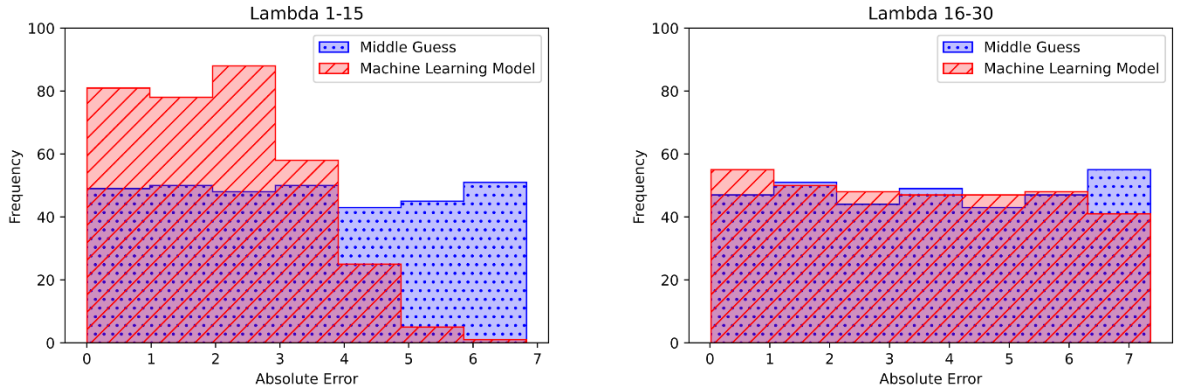

Figure 1: Left: Absolute error distribution of machine learning model estimate compared to a mean guess with Lambda values ranging from 1-15. Error being less signals that the model did work in this range of lambda. **Right:** Absolute error distribution of machine learning model estimate compared to a mean guess with Lambda values ranging from 16-30. Error being similar signals that the model did not work in this range of lambda.

Using Physarum polycephalum Microplasmodia to Detect Harmful Chemicals in the Environment

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Abstract: *Physarum polycephalum* (commonly known as 'slime mold') is a unicellular eukaryote that contains multiple nuclei, yet lack neurons. Slime molds have been shown to be able to express complex behavioral responses to their environment. In this research project, we focus on harnessing *Physarum polycephalum* as a living biosensor to detect harmful chemicals in the environment by making use of the organism's behavior. The research problem in this research project is being able to culture this slime mold in a liquid medium that will allow for the slime mold to be broken up into slime mold particles, and using this to run experiments where the slime mold would be spread uniformly by spraying it on a petri dish that has attractants and a petri dish that has repellents. The aim of this experiment is to demonstrate that the slime mold biosensor can detect the presence of environmental stimuli by moving towards the attractive stimuli and away from the repulsive stimuli. The significance of this experiment is that this slime mold could be used in the real world in the form of an aerosol spray, and will be able to detect chemicals of interest in a novel environment, and also provide information about the spatial distribution of the chemical.

The research methods first begin by making a nutrient rich liquid growth medium that the slime mold will be placed in. This is first done by mixting 10 grams of Bacto tryptone, 1.5 grams of yeast extract, 11 grams of D(+) glucose monohydrate, 3.87 grams of Citric acid monohydrate, 0.084 grams of Iron(II)sulfate heptahydrate, 0.6 grams of Calcium chloride dihydrate, 2 grams of Potassium dihydrogen phosphate, 0.25 grams of magnesium sulfate heptahydrate, 0.07 grams of manganese(II)chloride dihydrate, and 0.034 grams of Zinc sulfate heptahydrate all together with 1 liter of MilliQ water. Next, 20 mL of Hemin solution is added and the pH is adjusted to 4.6 with 4M of NaOH. Then, the growth medium is autoclaved and after cooling the growth medium is poured into an erlenmeyer flask and tilted about 45 degrees. The slime mold is introduced into the flask by placing it just above the growth medium and allowed time to discover the medium on its own. After 24-48 hours, the slime mold should be on the growth medium and covering the surface. Afterwords, the flask is ready to be placed on a shaker in which the flask will be constantly moving and breaking up the slime mold as it does and this is how the slime mold will break into particles, also known as "microplasmodia".

The results show that in the process of making these cultures the slime molds were not able to survive within the growth media despite efforts to adjust the mixture used. Through incremental improvements in culturing technique, the work done showed that finding a method of culturing slime mold particles is possible. Further changes can be made to the culturing protocol and in future work this method of maintaining liquid cultures of slime mold microplasmodia can lead the way to slime molds being used as a biosensor spray. This spray can be used in a way to obtain quantifiable data about amounts and spatial distribution of harmful chemicals in the environment making this process of gathering information safer. Another major advantage of using slime mold as a biosensor is that it is made of purely biodegradable material and poses minimal threat to the environment.

Quantitative Study of Cell Detachment Using Optically Computed Phase Microscopy (OCPM)

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Abstract: Optically Computed Phase Microscopy (OCPM) is an imaging technique which allows label-free imaging of cell structure. Uniquely, in OCPM, three-dimensional phase unwrapping is used to yield accurate images that are able to show the change in the cell over time. Rather than values being unwrapped in only the x and y dimensions, they are also unwrapped in t, time. Images were taken over time as a HeLA cell detached from a substrate. These images were labeled for ground truth images and were used to train a convolutional neural network (CNN) called U-Net on MatLab. This AI (artificial intelligence) approach allows the quantification of the time scale of cell detachment. Studying cell detachment drives advancements in many biomedical fields, for example cancer and tumor treatment. The formation of tumors, how a healthy cell breaks away and becomes a tumor cell, can be further understood. A method of quantification of the detachment process also helps artificial tissue research, to understand both how to grow artificial tissue and how the tissue will behave and interact with other cells once it is in or on the body. Using MatLab Image Labeler, twenty-six images were labeled as a provided ground truth with three pixel labels, "background," "unwrapped_phase," and "wrapped_phase." The network was trained and used for segmentation. The segmentation was used for unwrapping of wrapped pixels. The unwrapped image provides the accurate value of optical path length, or distance to the cell from the light source. In this project, it was found that OCPM and MatLab U-Net can be effectively combined in order to segment and unwrap images of cells. The U-Net allows for segmentation with only few provided training images, which makes it efficient, and therefore viable for future research into cell detachment and dynamics. In the future, quantification of the time scale should continue to be researched. Quantification of detachment of different types of cells is a reasonable next step. Overall, OCPM images allow label free imaging of cells, as well as dynamic imaging. The U-Net allows efficiency in segmenting and unwrapping multiple images to analyze cell dynamics.

Estimation of Dermal Absorption of Chemical Agents Using Physiologically-Based Pharmacokinetic Models

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Chemical Warfare Agents are weapons of mass destruction mainly utilized in early wars to cause death and incapacitation by using the toxic properties of chemicals. These toxic agents have been dispersed in gaseous or liquid states that impose many different lethal effects to humans such as cancer. The skin is the most common route by which harmful chemicals enter the body. Deem it necessary, a framework that models the dermal absorption of chemicals is very important. Physiologically based pharmacokinetic (PBPK) is a computer modeling approach that assesses the risk posed by toxic chemicals and explains their mechanisms as the chemicals are transported through tissues and organs. The transportation between the tissues and organs can be recognized as a partial differential equation (PDE). This complex (PDE) can be broken down into ordinary differential equations (ODEs) by orthogonal Collection techniques. These complex equations are solved using the computational system Mathematica. This system was used to evaluate various liquid chemical agents, as they are diffused through the different layers of the skin.

Works Cited

Simon, Laurent. Distributed Parameter Estimation of Dermal Absorption of Chemicals ... https://www.researchgate.net/publication/303062814_Distributed_Parameter_Estimation_of_Dermal_Absorption_of_Chemicals_using_a_Physiologically_Inspired_Boundary_Condition.

Investigating the Impact of Extracellular Matrix Proteins on Spinal Cord Injury and Repair

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Spinal cord injuries (SCI) can lead to debilitating physiological conditions, such as loss of voluntary limb functions. Non-fatal SCI cases currently affect 300,000 people in the United States with around 18,000 new cases each year. Despite their prevalence, there are no clinical medical technologies to induce repair and regeneration after injury. This is due to complex biochemical pathways in the central nervous system (CNS) that cause progressive damage after the injury and innately inhibit repair of the damaged tissue. Therefore, there is a need for novel solutions regarding neural regeneration post traumatic injury in the spinal cord. We approach this issue by simulating SCI at the cellular level and exploring the use of extracellular matrix (ECM) proteins in inducing nerve growth and repair. Laminin and nidogen-1 are ECM proteins found with the basal lamina of the peripheral nervous system and participate in myelination of axons through Schwann cells. However, the myelinating cells of the CNS are oligodendrocytes, not Schwann cells, and hence the impact of ECM proteins, especially nidogen-1, on neural growth and repair is largely unknown. By analyzing how these proteins affect neuron growth and guidance, we aim to build sophisticated hollow collagen gel models of neural networks *in vitro* to better understand nerve regeneration and repair.

Developing Baseline Levels of Pain Biomarkers in Healthy Volunteers

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Abstract: The goal of this research is to develop biosensors that will help assess the levels of pain biomarkers in patients, that will be used as a clinical tool for physicians to prescribe proper drugs and dosage. In order to accomplish this objective, it is important to establish baseline levels of pain biomarkers in healthy individuals to provide a comparison. Criteria for selection of participants in this study have been chosen to avoid any internal and/or external interference to ensure that our population is physically and mentally healthy. The participants will participate in a pain experiment that will include variable temperatures and intensities of heat for collection of pain biomarker samples (Table 1). Analysis of samples will be done using enzyme-linked immunosorbent assay (ELISA) techniques for detection and study of three pain biomarkers which include Contactin-1(CNTN-1), Inducible nitrous oxide synthase (iNOS), and Cyclooxygenase-2 (COX-2). Future research and development of this study includes adding in pleasure and stress detection elements for baseline detection of biomarkers.

Table 1. Summary of Pain Experiment with different intensities of heat with 50 participants for sample collection.

Type of Heat	**Temperatures**	**Trials**	**Participants**	**Total Samples/Pain Level**
Warmth	38ºC	3/person	50	150
Painful heat 1	43ºC	3/person	50	150
Painful heat 2	45ºC	3/person	50	150
Painful heat 3	50ºC	3/person	50	150
Total Number of Samples				**600**

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Nano-Silicate Reinforcement of Gelatin Methacrylate for Bone Regeneration

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Gelatin is widely used as a scaffold in tissue regeneration due to its ability to promote cell proliferation and adhesion. However, poor mechanical strength limits its application for bone tissue regeneration. Three-dimensional (3D) printed scaffolds are fragile and unable to maintain their shape when transferred to area of use. In this project, gelatin methacrylate (GelMA) was mixed with nano-silicate (Laponite RD) to improve the mechanical, biological, and chemical properties of gelatin-based scaffolds. Laponite is an insoluble synthetic layered silicate with shear thinning properties in aqueous solutions. Three GelMA-Laponite concentrations of 5% GelMA-0% Laponite (w/v), 5% GelMA-1% Laponite (w/v) and 5% GelMA- 2% Laponite (w/v) were prepared for this study. Swelling and compression mechanical characterization and Live/Dead assay was performed to quantify the effect of laponite on GelMA.

In this study, simulated body fluid (SBF) was used as an *in vitro* medium for bone regeneration. The elastic modulus of GelMA samples at equilibrium swelling significantly increases by approximately 78% and 288% when 1% and 2% Laponite are added respectively (Fig.1B). The swelling ratio of GelMA-Laponite samples at higher laponite concentrations is lower after 24 hours in DPBS, therefore, indicating that laponite successfully improves the structural integrity of gelatin when the concentration is increased by 1% and 2% (w/v) (Fig.1C). The live dead assay results (Fig.1D) show that cell viability was >80% on Day 1,3 and 5 for all three hydrogel combinations. As indicated by Fig.1 the addition of Laponite effectively improves the mechanical strength and structural integrity of GelMA scaffolds without compromising its biocompatibility. Future work will include Rheology, FTIR and SEM imaging for material characterization following *in vitro* modelling for bone regenerative applications. A delivery method will also be devised to inject the hydrogels onto bone defect with growth factors and stem cells.

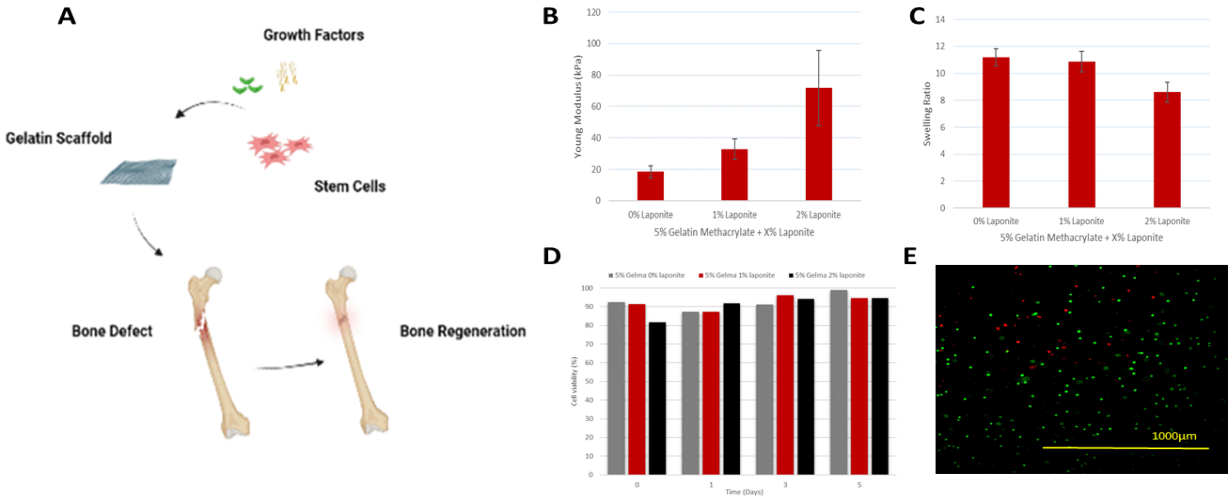

Figure 1: A) Schematic diagram of bone regeneration with gelatin scaffold. **B)** Compression test at equilibrium swelling in DI water. **C)** Swelling test after 24hrs in DPBS on freeze-dried samples. **D)** Cell viability analysis **E)** Live Dead Assay

Effects of Di-2-ethylhexyl Terephthalate on Ovarian Function in Adult Mice

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Phthalates, which serve as plasticizers in numerous plastic products used in commodities from children's toys to medical tubing, are endocrine disrupting chemicals that can impair the reproductive system of males and females at everyday levels of human exposure. As a result, common phthalates such as di-2-ethylhexyl phthalate (DEHP) are being replaced in consumer products by alternative chemicals that have not been safety tested to avoid the endocrine disrupting properties of phthalates. Di-2-ethylhexyl terephthalate (DEHTP) is a structural isomer of DEHP and rising phthalate replacement. Although DEHTP is increasing in consumer products, its health consequences are not fully understood and it may turn out to be a regrettable replacement with endocrine disrupting properties. The aim of this research is to investigate the impact of DEHTP on adult ovarian function using a mouse model. The ovary is a female reproductive organ that produces oocytes, or eggs, and female sex hormones. Follicles are the functional unit of an ovary, which contains an oocyte surrounded by granulosa cells. This study focuses on histologically studying the effects DEHTP has on follicle development, or folliculogenesis. Adult CD-1 mice are orally dosed with control (corn oil), 10 ug/kg DEHTP, 100 ug/kg DEHTP, or 100 mg/kg DEHTP per day for 10 days. The mice are then euthanized and sections of treated mouse ovaries are stained and follicles are counted at different developmental stages: primordial, primary, preantral, and antral. The number of abnormal/atretic follicles are also counted. Statistical analysis will then be conducted to observe statistical significance of follicle counts of DEHTP treatments when compared to the control treatment. We expect to find that follicle development is disrupted given greater dosages of DEHTP, which will suggest that DEHTP exposure is harmful to the ovary.

Neuronal Loss and Microglial Activation after Low-Level Blast Injury

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Explosive weaponry such as IEDs accounts for over 50% of traumatic brain injury (TBI) in 21st-century warfare. The sudden detonation of these explosives causes the release of a shock wave that can cause TBI. This causes neuronal death and the neuroprotective activation of immune cells in the central nervous system called microglia. This project measured the timeline of neuronal loss and microglial activation up to 48 hours post blast injury. A mouse model containing 20 mice in 4 groups - Sham, 4 hours, 24 hours, and 48 hours - was used to provide novel insight into microglial activation and neuronal death after blast injury. 3 blasts at the pressure 70 kPa ± 5 kPa (10.1526 psi) were administered to all groups at 10-minute intervals except Sham, which received all other treatment. The mice were sacrificed at 4 hours, 24 hours, and 48 hours post injury in accordance with their group and their brains were sectioned and mounted onto slides. The sections were stained with Fluoro Jade and Iba-1 antibodies to indicate dying neurons and activated microglia respectively. The results of this experiment will show the timeline of brain damage after blast injury, demonstrating at which point treatments can be administered. Future work will include testing therapies for blast injury at the favorable time points discovered in this study in order to optimize neural preservation.

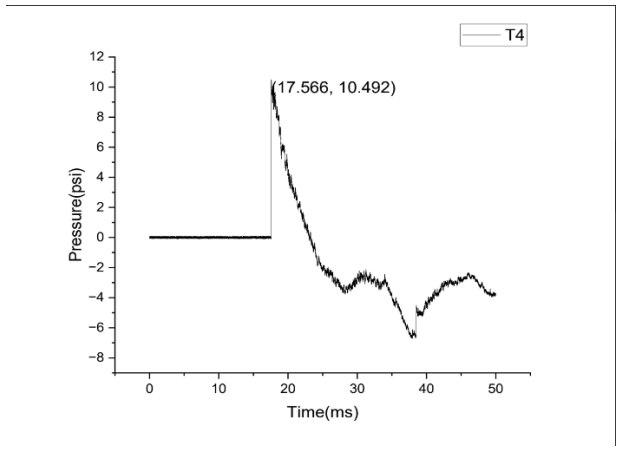

Fig.1. Graph of pressure change during blast, with peak pressure of 10.492 psi (72.855 kPa) at time 17.566 ms marked.

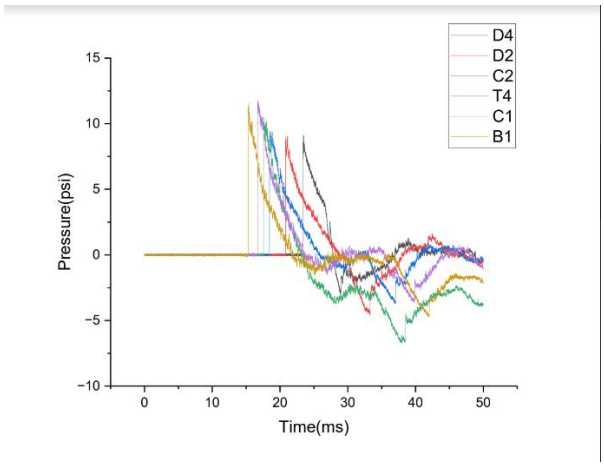

Fig.2. Graphs of pressure change during blast, with each reading sensor on the blast tube represented in a different color.

Effects of Botulinum Neurotoxin Injections on Gait in Children with Cerebral Palsy

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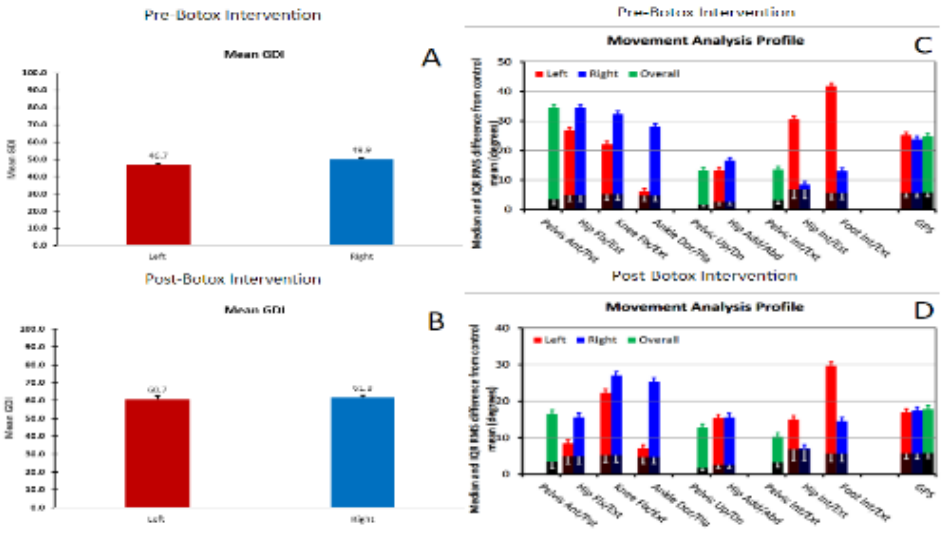
The goals of this study are to process 3-D gait analysis data and calculate gait deviation indices to quantify the changes in gait pre- and post-Botox interventions in children with Cerebral palsy (CP). CP is the most common childhood physical disability that results in motor impairments, specifically high levels of spasticity, caused by brain injury during the brain's developmental stages. The most common intervention used to counteract the effects of spasticity is the botulinum neurotoxin type A, or Botox, injection to weak regions in the child's lower extremities. Botox effectively blocks the release of acetylcholine neurotransmitters, which gives rise to the inhibition of the muscle's ability to contract, providing temporary spasticity relief. The Life Sciences Motion Capture lab is fully equipped with 17 Vicon V8 infra-red cameras, a 16-channel Delsys Trigno wireless EMG system, and wearable sensors. Sixty-one retroreflective markers were placed on anatomical landmarks of the subject to collect kinematic data. Surface EMG electrodes were used to quantify the subject's muscle activation during gait activities. Subjects were asked to walk on built-in force plates that help collect and analyze data on ground reaction forces. Custom scripts have been implemented to calculate common gait deviation indices: Gait Deviation Index (GDI), Gait Profile Score (GPS), and Movement Analysis Profile (MAP). The GDI of 1 CP subject with botox intervention showed improvement in both legs (left: 46.7 to 60.7; right: 49.9 to 61.8). The MAP showed improvement in the pelvic anterior/posterior movement (34.5 to 16.6), hip flexion/extension movement (left: 26.9 to 8.5; right: 34.4 to 15.6), hip internal/external rotation (left: 30.6 to 15.0), foot internal/external rotation (41.8 to 29.7), and GPS showed improvement as well with left leg going from 25.2 to 16.9 and right going from 23.9 to 17.5 (with overall



Figures: (A and B) Mean GDI of CP subject before and after botox intervention. (C and D) MAP of CP subject before and after botox intervention.

The Study of PTSD in Rats through Blast TBI

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Post-Traumatic Stress Disorder (PTSD) has been an unsolvable neurological illness for centuries. The largest group of people in the world that PTSD affects are war veterans. The goal of this PTSD research design was to gain more knowledge about the brain to get closer to a cure. The 24 Sprague-Dawley rats were split into 4 subgroups: blast, stress, blast and stress, and sham. They went through a series of behavioral tests studying their motor and cognitive deficits, stress, and depression. The animals underwent an additional stressor known as predator scent stress, cat urine, for 10 minutes and received three consecutive 70 kPa blasts. Before the animals got blasted or stress was induced, their blood was taken as a baseline for their glucocorticoid levels. Then, after the stress and before the blast, their blood was drawn again to determine their stress levels from the cat urine. The tests consist of the open field test (OFT), studying anxiety and depression, elevated plus-maze (EPM), looking into their anxiety, depression, and motor deficits, and novel object recognition (NOR) and novel object location (NOL), which studies the animals' cognitive deficits such as their memory. These tests were run 24 hours after the last injury inflicted on the animal. Moving forward, the same behavioral test will be run again at three more time points: day 7, day 45, and day 60. After day 60, an acoustic startle response (ASR) test will be run to look into the animal’s auditory deficits. Once this is complete, immunostaining will be used to look into specific proteins in the amygdala and hippocampus regions of the brain. Understanding the results from these tests helps better understand how to approach the issue of PTSD and look into different chemical and therapeutic cures.

Effect of Injury and Cytokine Addition to Live Astrocyte Cultures

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Abstract: The goal of this project was to study the effects of adding Interleukin-6 (IL-6) and Lipopolysaccharide (LPS) to astrocyte cultures, as well as the effects of injuring the culture between a 40-50% strain rate. To date, no interventions exist for the treatment of traumatic brain injury (TBI), despite it accounting for more than 223,135 hospitalizations in 2019[1]. Those who suffer from mild TBI have been shown to undergo cognitive and motor deficits long-term. *In vitro* systems have been created to study the mechanistic underpinnings of TBI. Using these types of *in vitro* models has yielded that (1) neuronal activity changes acutely after injury and that (2) astrocytes, the support glia, become activated after injury. Despite these findings, minimal research has been focused on astrocyte viability in acute injury. The goal of this study is to observe astrocyte phenotypic and viability changes after injury, specifically in short periods of time directly after injury, as well as viability in a cytokine-saturated environment, which leads to death in pure neuronal cultures.

A stretch device using a CO_2 tank was used to stretch multiple cell culture wells, with strain rates ranging from 40-50%. Other wells were cultured in 50 nL of IL-6 and LPS respectively. IL-6 was kept to a concentration of 1 μg/mL in all cultures. Non-injury and injury cultures were maintained for a two week period with media changes occurring twice weekly. Upon injury, the cells were returned to the incubator for a period of 1 hour, after which they were removed and imaged immediately to observe acute reaction or death. IL-6 and LPS cultures were cultured in each cytokine respectively for a period of one week, with two media changes. Zombie green viability dye was used to stain for cell viability in each culture at a concentration of 1 ng/mL.

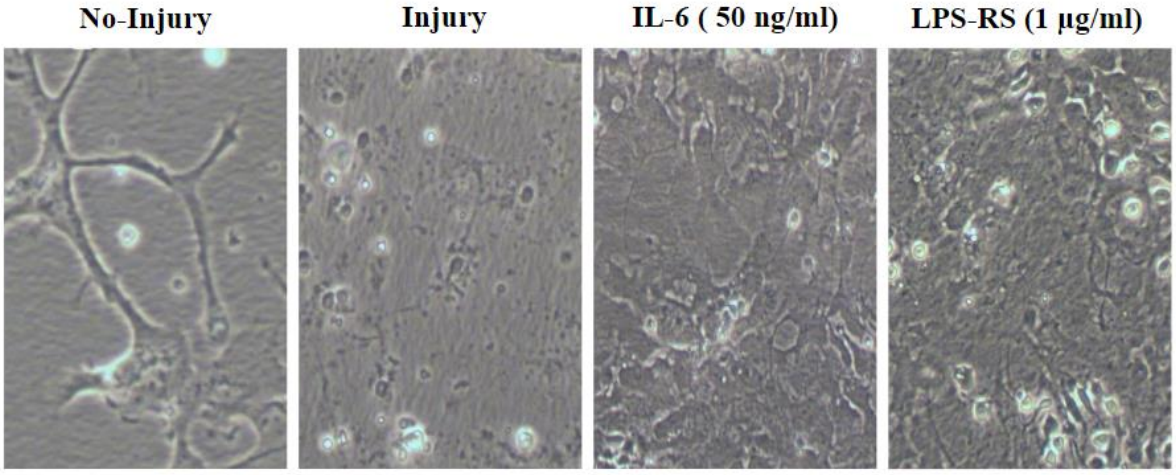

Figure 1: Astrocyte cultures when injured through blasting to 48%, exposed to 500μL of IL-6, and exposed to 1μg/mL of LPS. Cell death became prevalent under 48% strain with no large changes in exposed cultures.

Identifying the Heterogeniety of Autism Spectrum Disorder Using Structural MRI Images Compared to Other Nueropsychiatric Disorders

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Abstract: The aim of the research is to investigate the key differences of brain development of children and adolescents with Autism Spectrum Disorder(ASD) compared to both typically developing children (TDC) and other clinical conditions (non-ASD) using structural MRI images and behavioral measurements. Even today, there are no definite autism-defining structural biomarkers that indicate early development of the disorder. Thus, promising research in identifying these biomarkers can provide early identification and targeted treatments. In the following research, T1-weighted structural magnetic resonance images(sMRI) of participants between the ages of 5 and 21 years within the New York City Area, known as the Healthy Brain Network(HBN), can allow us to address clinically relevant questions about ASD's etiology.

The procedure includes decomposing the sMRI images into smoothed, warped, and normalized grey, white, and cerebrospinal fluid maps using a technique known as Voxel Based Morphometry(VBM). Using the probabilistic gray matter volume map of the included 715 subjects, statistical testing through a mass-multivariate approach, or analysis of voxel across subjects, can be performed. More specifically, a dimensional reduction technique known as Non-Negative Matrix Factorization(NNMF), as described by Sotiras et al, can be used to produce interpretable representation of the large grey matter volume maps into set of latency factors of voxel areas and weights for each subject. Later, normative modeling, or a regression technique known as Gaussian Process Regression(GPR), can be computed on the TDC group with latency factors as the response variable and age and gender as covariates allowing the creation of a normal grey matter volume chart, which is similar to use of growth charts in pediatric medicine. Next, using the regression model, the factor deviations of each of the factors can be estimated for the ASD and non-ASD group to measure the deviation of grey matter volume of the group with neuropsychiatric disorder compared to TDC. To assess the accuracy of ASD identification, clustering analysis was performed using Gaussian Mixture Clustering(GMC) with a preset of three clusters for the three groups. Moreover, subtypes of ASD were also classified using GMC to determine the heterogeneity or "spectrum" seen within ASD.

The result indicates that ASD displayed significant deviations in latency factors for some factors when compared to TDC and non-ASD. These factors are trained with a GPR model and the deviations are calculated for the test TDC, ASD, and non-ASD group. The data indicates that the classification using GMC between TDC and ASD when assessed individually with specificity of 0.68 and sensitivity of 0.79 for factor 18. Thus, these factors can provide biomarkers that can indicate if a person may have ASD or not using both their structural image and Social Responsiveness Scale score.

Effect of ECM Coating and Neurotrophic Factors on Nerve Regeneration in Collagen Gel 3D-Model

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Most existing models employed to study peripheral nerve regeneration are limited in their ability to capture the full range of interactions between the insoluble and soluble cues of the extracellular matrix (ECM). This research proposes a novel biomimetic model aimed to mimic the ECM environment. I will be investigating the influence of various ECM molecules (i.e. laminin, PDL, and fibronectin) in a 3D collagen model with dorsal root ganglia (DRG). The average and maximal axonal length will be determined through immunostaining of DRG cultures on biochemically defined surfaces and used to gauge the extent of peripheral nerve growth. These optimal concentrations will be applied in subsequent studies to assess the efficacy of a blend of ECM proteins coated onto a collagen gel 3D model. The interactions between the ECM molecules and varying neurotrophic factors (i.e. GDNF, BDNF, and NGF) will also be determined, specifically to identify any synergistic signaling on axonal growth. The development of a more realistic in-vitro model will allow for more efficient screening of potential drug treatments for various neurodegenerative diseases, resulting in improved clinical outcomes. Furthermore, after this study, a more comprehensive understanding of the intricacies of peripheral nerve regeneration will be achieved.

The Effects of Breathing Techniques on Blood Oxygenation Levels: An fNIRS Study

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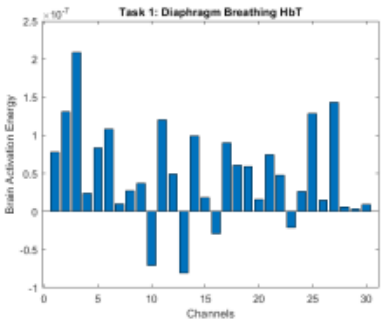
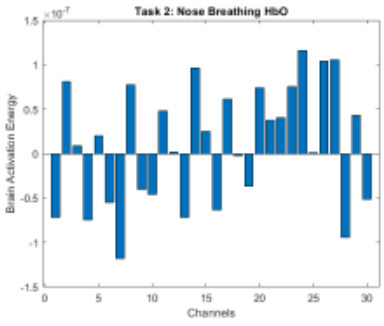
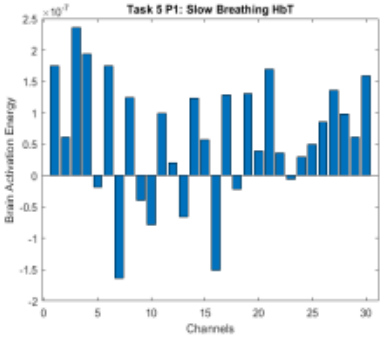
Functional Near-Infrared Spectroscopy (fNIRS) is a non-invasive brain imaging machine that can measure blood oxygenation levels in the brain. fNIRS, through the use of an adjustable brain cap, uses fiber optics placed on the cap to record brain activity while being connected to a computer. fNIRS is crucial when trying to measure hemoglobin and blood oxygenation levels in a specific part of the brain and allows for the analysis of processing brain functionality and information. (Chen 2020) In recent studies, the effects of breathing techniques have been shown to improve blood oxygenation levels and have been studied using fNIRS.

This project focuses on investigating the relationship between blood oxygenation levels and different breathing techniques, as well as the strength of the fNIRS signal. Our project design included collecting data from 33 healthy, human subjects ranging from 18-30 years old (13 females, 20 males). Participants filled out a pre-screening form to verify there was no previous or current history of psychological, respiratory, neurological, heart, or blood diseases and they were not on medication, pregnant, or have brain injuries. Subjects were asked to come into the fNIRS room once and perform five breathing techniques that included diaphragm, nose, mouth, breath-hold, and fast slow breathing (in this order), which were modeled through a block-coding program called E-prime. Data was collected to compare the blood oxygenation and paced breathing techniques to understand the fNIRS signal. Each activity (excluding the fast slow breathing) was then followed by a five minute break before moving onto the next cycle. A few data sets from specific participants were excluded, due to missing data points.

After data was collected, preprocessing of datasets was performed using Homer3, an fNIRS processing program through Matlab and further processed through bandpass frequency filters from 0.01-0.5 Hz, and a Motion Correction Wavelet. General-Linear Model (GLM) was used as post-processing methods to obtain results. Using GLM, we found Beta values that were then averaged out for each channel. My study found a positive activation for most channels from 1-30 in diaphragm, nose, and slow breathing. This indicated the amount of HbT was increasing while participants were performing these tasks (see figures below). This project supports that there may be a relationship between specific breathing patterns and cerebral hemoglobin levels through using fNIRS. Future studies may be implemented to study the five-minute break (resting state) after each task, as well as the correlation between age and hemoglobin levels, or the correlation between male and females for breathing.







Detection of PFOA through an Electrochemical EIS Microfluidics Platform Named ESSENCE

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Public vulnerability to biochemical threats posed by widespread and extensive anthropological uses of per/polyfluoroalkyl (PFAS) water contaminants establishes urgency for rapid, ultrasensitive, and selective technology for chemical/biological/radiological/nuclear/environmental (CBRNE) forensics and detection. These contaminants that are widely abundant in our day to day lives for decades and weaponize against an individual's body to develop cancer with prolonged exposure and/or when consumed. Perfluorooctanoic acid (PFOA) is one of the most dominant environmental contributors, and its half-life in water has been estimated to be longer than 92 years. Therefore, the monitoring of PFOA level in the water source is needed. To date, PFAS analysis is predominately based on high-performance liquid or gas chromatography-mass spectroscopy. However, these methods suffer some limitations in practice, such as ex-situ analyses (not adaptable for field-deployment), time-consuming, high cost. Our electrochemical impedance spectroscopy (EIS) platform technology is a rapid, sensitive, and selective detection technique for rapid screening of PFOA in the field in the source water. With current limitations of electrochemical sensors, the objective of the designed metal-organic framework (MOF) microfluidic impedance sensor platform model is to expand the device's sensitivity capacity with defined calibration curves using Zirconium based MOFs (UiO-66 and its derivative (UiO-66 NH2)). This application aids to the development of a microfluidic, affinity-based electrochemical sensor platform for a sensitive and analytical impedance detection of PFOA. The high frequency operation of the UiO-66 and UiO-66-NH2-based MOF receptor probes in the microfluidic channels coupled with a non-planar interdigitated microelectrode design and ground water solutions through an impedance analyzer enables proof-of-concept by demonstrating the presence of minute quantities of PFOA, then ultimately other environmental contaminants with appropriate receptor probes and design. It may also be synergized with other approaches to enhance CBRNE detection entirely to develop electrode/probe/target interaction at the molecular level.

Role of TGFβ in Hair Follicle Regeneration

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Large wounds affect over 6.5 million people and often result in scarring with incomplete wound closure. These scars remain with the individual lifelong and there is yet to be a solution to fully reverse scarring from wounds. The main steps involved in scar reversal include skin epithelialization in wound healing, followed by hair follicle regeneration, which ultimately allows for scar reversal. The dermal papilla serves as an indicator of hair follicle regeneration, as it is composed of mesenchymal cells and regulates hair growth. Previous research suggests that the transforming growth factor beta (TGFβ) signaling pathway is involved in the process of wound healing. However, the role of TGFβ signaling in hair follicle regeneration remains unknown. I would like to determine whether the TGFβ signaling pathway is required for hair follicle regeneration so that it can possibly be used to allow for complete wound closure and scar reversal. This research would benefit an immense number of patients and potentially advance tissue regeneration technology to heal burn victims and those suffering from large wounds.

In order to do this, mice were used as mammalian models with wounds harvested in each of the mice. There were two main steps involved in experimentation. First, I confirmed that TGFβ is active at the site of the dermal papilla, which is the area of interest for hair follicle regeneration. I performed immunohistochemistry using fluorescence of pSMAD2, a downstream effector molecule of the TGFβ signaling pathway (Figure 1). The second step was to delete the TGFβR2 gene in order to determine the specific role of TGFβ. Doxycycline was injected into the mice hours after harvesting the wound to delete the TGFβR2 gene and the number of dermal papilla cells was counted in mice with the TGFβR2 gene deleted and compared to mice with the TGFβR2 gene intact. On the first day of wound harvest, there is a statistically significant decrease in the number of dermal papilla cells in mice without the TGFβR2 gene compared to those with the gene (Figure 2). This shows that TGFβ plays a crucial role in wound healing and hair follicle regeneration on the first day of wound harvest. However, on the ninth day of wound harvest, there is no statistically significant difference. Further experimentation is required to determine how long TGFβ continues to affect hair follicle regeneration after harvesting the wound. This will be done by injecting doxycycline at different points of time along the wound healing process, such as 2-3 days and 5-6 days after harvesting the wound.

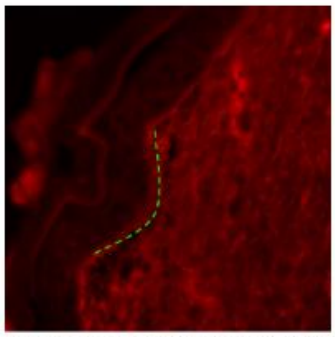

Figure 1. pSMAD2 fluorescence of dermal papilla indicated by green dotted line

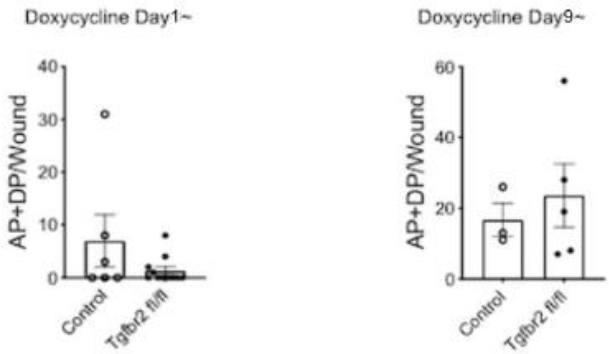

Figure 2. Hair follicle regeneration assay of mice with TGFβR2 gene (control) and without the TGFβR2 gene (TGFβR fl/fl)

Secreted Semaphorin Response to Neuronal Injury

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In the nervous system of some animals, including the mammalian peripheral nervous, injured nerve cells can regenerate and regain function after injury. In the mammalian central nervous system, such regeneration is very rare, due to cellular and tissue signals. Several signaling pathways that play a role in neural development also mediate and regulate neuroregeneration. One such signaling pathway is composed of semaphorins and their receptors, the plexins, which serve as guidance cues for the axonal pathways and are instrumental in regulating synapse formation during nervous system development.

The aim of this project is to determine the distribution of a diffused signaling molecule, a secreted semaphorin (MAB-20), and to detect spatiotemporal dynamics in its distribution after neuronal injury. MAB-20 unlike the other 2 semaphorins is a free-floating protein that is not membrane-bound like smp-1 and smp-2 (Figure 1). We are using molecular biology methods to construct a DNA plasmid and generate transgenic animals with fluorescently-tagged semaphorin. We will next use fluorescence microscopy to locate semaphorin molecules and deliver a precise neuronal injury with laser microsurgery while imaging the distribution of secreted semaphorin. The change in the distribution of the secreted semaphorin in response to neuronal injury can provide insight into its function and inspire therapeutic approaches to brain and spinal cord injuries.

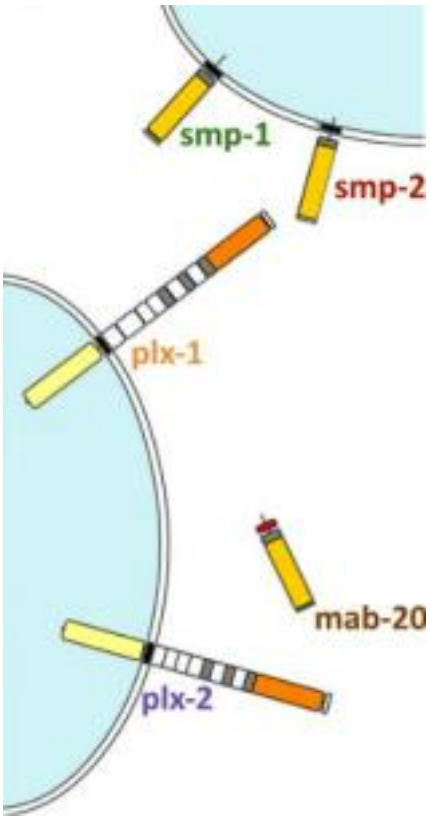

Figure 1: MAB-20 is the only secreted semaphorin in *C. elegans*.

Preliminary Assessment of Apoptotic Self-Assembling Peptide Hydrogels for Drug Delivery

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Abstract: Triple-negative breast cancer accounts for 10 to 15% of all breast cancer cases, with cases relatively more common among younger women and women of African descent. There are minimal expression estrogen receptors (ER), progesterone receptors (PR), and the human epidermal growth factor receptor 2 (HER2) protein in triple-negative breast cancer. The absence of these receptors limits the treatment options for patients of this subtype, as antibody and hormone therapy approaches lack a target. Consequently, the treatment options for clinicians in locally advanced triple negative breast cancer are limited. To address this clinical need, we designed shear-thinning, thixotropic multidomain peptide hydrogels, containing an apoptosis signaling domain. We hypothesize that these bioactive peptides have mechanical properties and structural properties to be administered as a localized therapeutic while signaling for cell death in tumor tissue margins following surgical resection. Hydrogels of the apoptotic peptides E2WEWT, SL(APOP2), and SL(APOP3) were characterized using rheology, circular dichroism, fourier transform infrared spectroscopy, and cytocompatibility assays to determine the injectability and cytocompatibility of the hydrogels.

The Role of the Hog1 Pathway in *Candida auris* Drug Resistance and Cell Wall Architecture

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Abstract: *Candida auris* is an emerging, multidrug-resistant (MDR) opportunistic pathogen that affects thousands of patients worldwide with mortality rates of up to 75%. This species exhibits phenotypes associated with high transmissivity and high pathogenic burden, including skin colonization, environmental persistence and the formation of highly adhesive biofilms. Troublingly, current antifungal treatments such as echinocandins, azoles and polyenes which disrupt cell wall integrity have limited efficacy against *C. auris*, making clinical management highly challenging. Mechanisms by which *C. auris* switches from the commensal (non-invasive) form to the pathogenic (highly invasive form) and responds to environmental stresses have not been fully elucidated, but this is an area of ongoing research as a part of efforts to identify novel drug targets and therapies.

Research involving other members of the *Candida* genus suggests that the Hog1 pathway - one of many fungal pathways with both a two-component signaling (TCS) and mitogen-activated protein kinase (MAPK) signaling component – is involved in virulence, adhesion, drug resistance, and morphogenesis. Targeting this pathway could serve as an alternative or as a supplement to existing antifungal therapeutics, providing a means by which to abrogate fungal responses essential for pathogenesis. Using a modified PCR-based fusion approach, we generated strains lacking the key proteins Ssk1 and Hog1, finding that these proteins are necessary for the resistance to antifungal drugs amphotericin B (AMB) and caspofungin (CAS) observed in clinical isolates. Ssk1 and Hog1 also play a role in cell wall function and stress adaptation through extensive crosstalk with other TCS-MAPK pathways, specifically the Cek1 and Mkc1 pathways (Figure 1). Given that TCS signaling is not present in humans, our findings suggest that designing antifungal drugs to target the Hog1 pathway could yield solutions to the problem currently posed by drug-refractory *Candida auris* by restoring drug susceptibility without additional side effects.

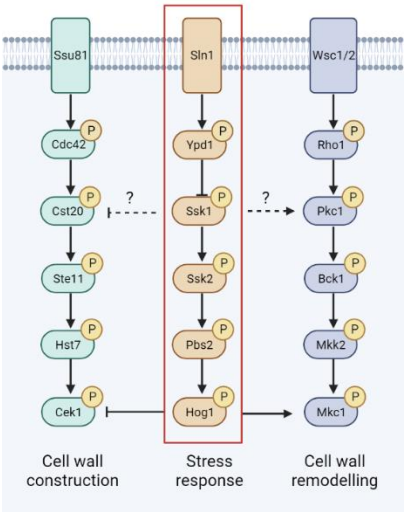

Figure 1: Crosstalk between the Cek1, Hog1, and Mkc1 pathways governs the response to cell wall stresses in *Candida auris*.

Predicting New Peptides That Self-Assemble into Amyloid-Like Fibrils

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Amino acids are the building blocks of proteins which are made of peptide sequences. Peptides are the primary structures of proteins that must function through the proper folding of proteins. However, there have been a number of peptides discovered to be intrinsically disordered, such that they tend to aggregate forming amyloid fibrils, which has been proposed to be the culprit of amyloid diseases such as Alzheimer's and Parkinson's. There is no clear answer as to why the misfolding occurs between peptides. Here, we are going to predict peptides' self-assembly into amyloid-like fibrils by employing short amphipathic amino acid sequences. The specific goals of the research process is to identify the causes behind the misfolding of proteins and finding the best peptide sequence. Research on this topic will bring light to many questions regarding the structure and function of proteins. This research will aid in finding cures to many incurable neurological diseases. Furthermore, this topic of research will play a role in medicine and bioengineering fields, which use the formation of proteins to come up with alternative solutions for fighting diseases and injuries. The research objective is to use software GROMACS and NJIT's supercomputer Lochness to predict different peptide assemblies to use in the medicine and engineering fields. This prediction can give some insights into the development of new therapeutics to amyloid diseases and the application of biomaterials. It will also help in identifying the correlation between the different peptide sequences that misfold, aggregate or form fibrils. We ran and analyzed several simulations of many different peptide sequences that consisted of eight amino acids. Each peptide sequence took 8-10 days to complete and was analyzed at 500 ns and 1000 ns. The visualization of the simulation results revealed if the peptides formed fibrils or not. When fibril is formed by a peptide sequence it means there is a misfolding of protein. Proteins are supposed to form a stable 3D structure, however due to the misfolding they aggregate into forming fibrils. The peptide sequence that forms fibrils indicates that it may potentially be related to many neurological diseases. Several peptide sequences that were simulated resulted in fibril formation. Further research is needed to ensure the specific circumstances that cause peptides to aggregate into fibrils.

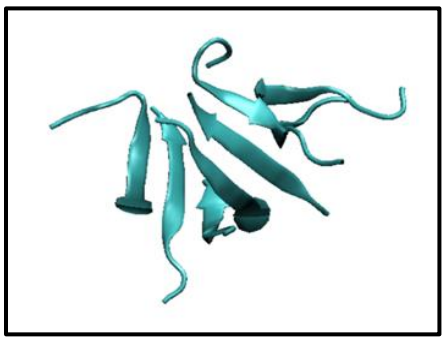

Figure 1: Peptide sequence AKAEFKFE fibrils after the simulation

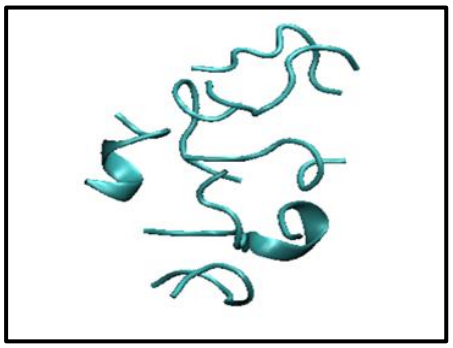

Figure 2: Peptide sequence KFFKEFFE formed only aggregates after the simulation

Repeated Low Level Blast Injury Induced Neural Loss

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Abstract: Repeated low level BLAST injuries are a specific type of diffusive injury that impacts all parts of the brain. Members of the military and law enforcement personnel suffer from these types of injuries every year during their training sessions, and though overt symptoms are not observed, long-term behavioral deficits are apparent. Cognitive dysfunction, attention deficits, and sleep disturbances, amongst other symptoms have been reported. Previous research suggests oxidative stress as the cause of neural loss in long-term neurodegenerative diseases, which may explain the behavioral deficits. There are similar explanations for these behavioral changes after mild to severe traumatic brain injury (TBI), but not for the rLLB model. Based on the mechanisms for behavioral changes caused by neuronal loss post TBI, a possible explanation arises. Hypothesizing a potential mechanism for rLLB related neuronal death involves relating the known mechanism of how rLLBs affect the brain, involving hyperproduction of (ROS), and putting the brain into a state of oxidative stress. Oxidative stress is caused by an excess of reactive oxygen species (ROS) in the brain. A small amount of ROS is necessary for the body to neutralize free radicals and other harmful pathogens, but the current theory is that the amount of ROS in the brain spikes after rLLB, to cause the brain to go into a state of oxidative stress. This stress in turn, may lead to inflammation pathways which are proven to trigger cell death, in this case, of neurons. The principle behind this experimental design is to link the ROS and oxidative stress to the inflammation, and the inflammation to the neural loss, thereby supporting the theorized mechanism in two steps. Supplementing the biochemical aspect will be the behavioral studies on the animals, including By putting animal groups through the injury, studying their behavioral activity, and using a series of specific stains, the proposed mechanism for neuronal death can be confirmed or denied. This research will unlock a new depth of understanding on the brain and how seemingly inconsequential injuries may lead to catastrophic biochemical changes.

Investigating the Role of a Genetically-Conserved Spinal Neuronal Class, *Dmrt3*, in the Control of Locomotion and Fin Movement in Zebrafish

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Abstract: Neurons are considered to be the fundamental units of the brain and spinal cord which ultimately control various functions such as locomotion. A neural circuit is a more complex system of neurons where a population of neurons are interconnected by synapses to form large networks that can perform a specific function when activated. By understanding these neural circuits we further understand motor behavior and disorders. This project focuses on exploring spinal interneurons in the larval zebrafish and how they are linked to the *Dmrt3a* gene. Previous studies have identified these interneurons in other organisms such as mice where they have been associated with locomotion. We hypothesize that the activity of *Dmrt3a* neurons is essential for coordinating locomotion at different speeds. To test this hypothesis, we quantified the locomotion of larval zebrafish with and without active *Dmrt3a* interneurons, and the potential effects of the stimulation of these interneurons when the larvae are at rest or swimming embedded in agarose gel. This helps further our understanding of the neural circuits underlying locomotor control in vertebrate animals.

This study is important as it aims to learn more and understand neurons and neural circuits and how they affect locomotion in zebrafish. Understanding locomotion is important as it is vital for zebrafish and their essential daily processes. By focusing on the spinal interneurons linked to the *Dmrt3a* gene, we can get a better idea of how locomotion and speed-shifting work. Using this knowledge, it would be possible to extend these findings to other tetrapods and animals such as mice or humans. This is because the coordination of limbs such as the pectoral fins is related to tetrapods which are considered to be one of the ancestors of land-dwelling organisms such as humans, in an evolutionary aspect. This means that any potential findings regarding locomotion, such as the movement of the pectoral fin, can be applied to the understanding of the coordinated movement of limbs in humans. Also, some of these findings in this study may also help us understand neurological disorders relating to locomotion better.

With our experimental setup, we can test if fish have changes in their locomotion with or without functioning *Dmrt3a* neurons. As mentioned before, we have two groups, a control group with functioning *Dmrt3a* interneurons and an experimental group with silenced *Dmrt3a* neurons. Both groups go into the behavior rig where data is collected, then analyzed through DeepLabCut and MATLAB. Three speeds of the OMR grating motion are tested at random to induce different swimming speeds. The data collected; tail-angle, tail-beat frequency, bout duration, interbout duration, bout distance, and average swimming speed, versus grating speed, will help us determine if there are changes in locomotion due to the silenced *Dmrt3a* interneurons.

With the preliminary data and analysis we have collected, we can state that *Dmrt3a* does play a role in coordinating locomotion at different speeds. We measured any potential swims and movement struggles in both the control and experimental group, and it was found that the control group had more struggles than swims and the experimental group had more swims than struggles. This shows that silencing of the *Dmrt3a* interneurons is affecting movement in some way and further analysis will provide better reasoning.

Theory-Guided Control of Dye-Host Systems: Aggregation and Photophysical Properties

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Abstract: Controlled emission of fluorescent organic molecules has wide implications in biosensing, dye-sensitized technology, and data storage. Encapsulation of such molecules in water-soluble molecular cages is a novel strategy for controlling their aggregation and the corresponding photophysical properties. Here, we evaluate the thermodynamic stability of various boron-dipyrromethane (BODIPY) and squaraine based organic chromophores encapsulated in hybrid supramolecular cages. $Pd_xL_y^{n+}$ cages with different sizes are paired with 4 Squarine and 4 BODIPY-based dyes. These complexes are then evaluated with the dye in various positions around and inside the molecular cage. In order to do so, electronic structure calculations using the Gaussian package were employed to identify the best supramolecular complexes for the desired application with the main criteria being structural compatibility of the host cage and the guest dye and thermodynamic stability of the resulting complexes. Future work includes evaluating the photophysical properties by calculating the absorption/emission spectra of the host-guest complexes relative to the free dyes. The most promising structures would then be introduced for synthesis and experimental verification.

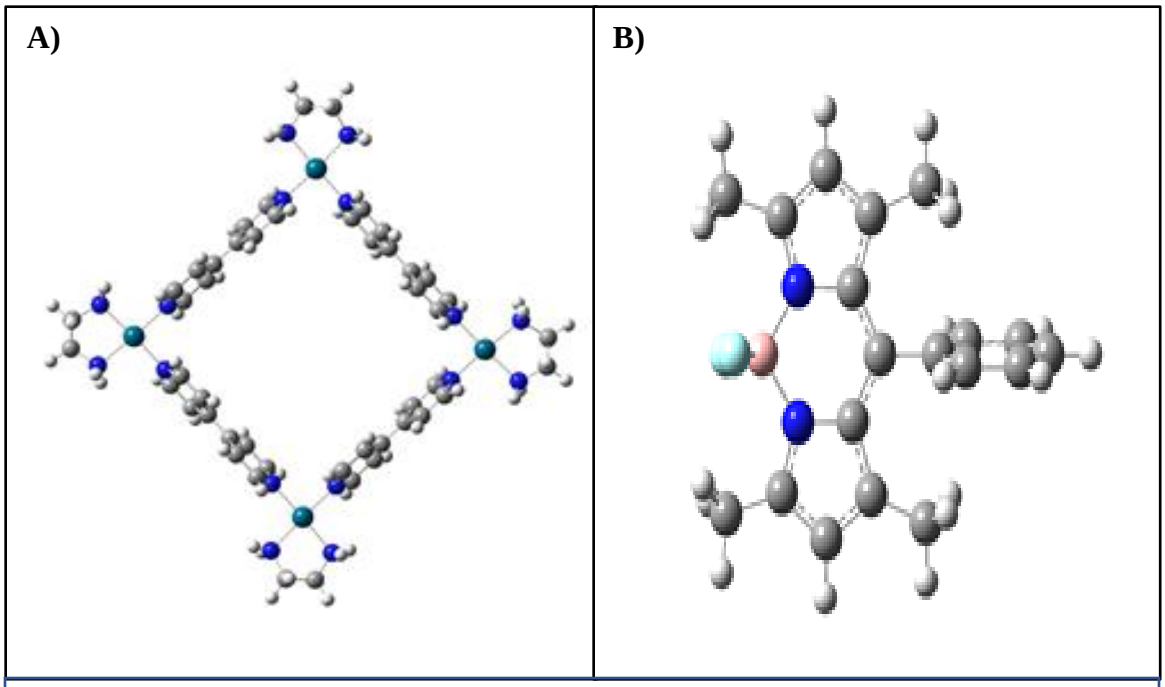

Figure 1: A) $Pd_xL_4^{8+}$ Cage optimized in implicit solvent **B)** BODIPY Derivative optimized in implicit solvent

Computational Exploration of the Gewald Reaction

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The Gewald reaction is an organic transformation that synthesizes aminothiophenes: sulfur-bearing compounds with extensive use in the creation of pharmaceuticals, optoelectronics, and synthesis of larger macromolecules. The reaction consists of two steps: Knoevenagel-Cope condensation of a ketone and cyanoester, and the addition of elemental sulfur to the formed nucleophile (Figure 1). This latter process is debated and understood poorly within literature, as the mechanisms for sulfur addition in general bear little experimental evidence. To investigate this mechanism, we used the computational program Gaussian 16 to explore various potential pathways within the scheme, compute free/reaction energies, and locate several transition states. We used the ωB97X-D method with the aug-cc-pVDZ basis set and SMD solvation model for acetonitrile. Through this work we aim to further the knowledge of aminothiophene synthesis, both in literature and possibly in terms of production efficiency, as well as contribute to analysis of other similar reactions.

To probe the reaction of sulfur with nucleophiles, we selected eight carbon nucleophiles and found their lowest energy conformers, both in their protonated and deprotonated state. We then calculated their respective reaction energies of deprotonation and used the resulting ΔG values to estimate their pKa. Our results match well with experimental data, confirming our computational approach. We also located transition structures and calculated their energy (Figure 2) From these reaction energies we found that more basic nucleophiles tended to have lower activation energies. As sulfur opening by the nucleophile is then followed by a poorly understood polysulfide decomposition, our next objective would be to locate various decomposition transition structures to elucidate the full mechanism of the Gewald reaction.

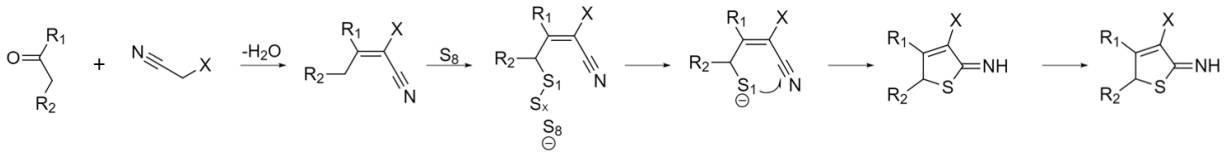

Figure 1: Suggested reaction pathway for one-pot Gewald reaction

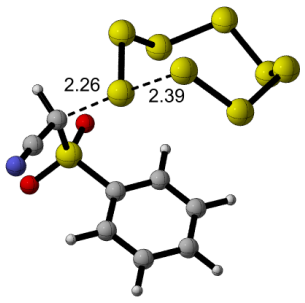

Figure 2: Located transition structure using phenylsulfonyl-acetonitrile as the nucleophile (bond length in Å)

Optimization of Cell-Mediated Gelatin Hydrogel for High-Efficiency Cell Migration

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Quantitative measurement of cell migration in three-dimensional (3D) cancer models is challenging because of biomaterial diversification. Cell migration in a 3D substrate is a key step in modeling cancer metastasis *in vitro*; however, there is limited knowledge regarding fabrication parameters of the biomimetic scaffolds that potentiate cell motility. The objective of this study is to analyze cell migration in a 3D model of solid tumor made of gelatin methacryloyl (GelMA), to optimize the biomimetic properties and obtain a protocol for further experimentation. The goals are I) to design a cell migration apparatus for microscopic data collection, and II) to analyze data and quantify cell migration for different compositions, stiffness values, cell densities and porosities.

This research was carried out by designing and 3D printing a cell migration apparatus composed of cell laden hydrogel using high and low methacrylate GelMA and human fibrosarcoma cells (Fig. 1A). GelMA has shown strong compromise for 3D cell culture for bioengineering due to its similar features for cell-laden constructs like cell adhesion and matrix functionalization. GelMA properties that enhance cell migration were tailorable with higher crosslinking time and lower degree of methacrylate. High degree of methacrylate may have the highest fidelity to physiological properties of the human body regulating cell motility. Increasing the composition percentage of GelMA in the cell-laden substrate represented decreased cell motility due to its stiffness and porosity reduction. Through various designs, the cell migration of fibrosarcoma cells were shown to be optimized through a high degree of methacrylate (8% w/v) with low percentage of GelMA (7% w/v) hydrogel. With these remarks, the research highlights that the gelatin composition, degree of methacrylate and design improve the fidelity and functionality of the cell-mediated hydrogel migration assay with further experimentation in 3D cell culture and applications in invasive tumor cells motility and drug repositioning. The next step of this project will involve applying this protocol to breast cancer cells and other tumor types.

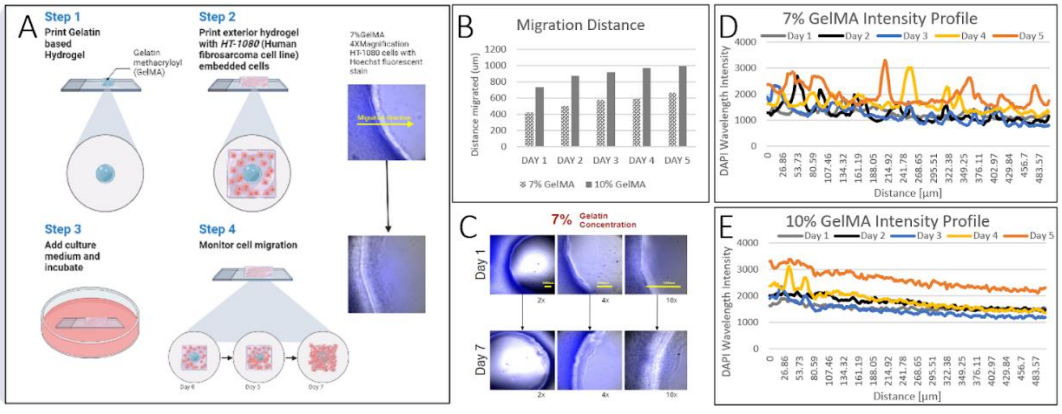

Figure #1: A) Preparation process of hydrogel-based migration assay mixed with GelMA and photo initiator at set concentrations and 3D printed with digital light printed. **B)** Migration Distance in micrometer/time. **C)** Optimized 7% GelMA microscopic migration day 1 and day 7. **D)** 7% GelMA DAPI Intensity Profile Intensity/micrometer. **E)** 10% GelMA DAPI Intensity Profile Intensity/micrometer.

Electrochemical Impedance Based Biosensor to Detect Biomolecules

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In the age of the COVID-19 pandemic, a greater need for rapid point of care (POC) devices has emerged without a sufficient number of them currently being utilized in healthcare. As a result, a diagnostic of a disease a patient may have takes time and a sample to be sent to a lab and have a test conducted. A portable diagnostic device, however, can accomplish this without the need for a lab test to be conducted. Even within this class of devices, there is a lack of portable diagnostics that are capable of detecting toxin molecules in the fluids of the body. The ESSENCE portable platform is capable of doing so, and in addition, can analyze the biomolecules in the fluid. The device proposed using ESSENCE is one that has a unique electrode structure. It incorporates better electrofield distribution, high shear forces that improve the selectivity of the device, packing that improves the selectivity, and a higher frequency to improve the speed of toxin detection. The device is assembled by creating a channel including the electrodes on a chip and filling the packing into one of the electrodes with another chip layered on top. Determination of the packing material is dependent on the toxin being tested, and can be modified by functional group. The focus of the tests on the device was mycotoxins, of which three were tested: Anatoxin-A, Cylindrospermopsin, and Microcystin. ssDNA detection was also tested on the device, and the functional probe used is single stranded DNA.

Monoaminergic Neuromodulation of Internal State

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Disproportionate neuromodulator concentrations are the root cause of many neurodegenerative, physical, and mental diseases. These diseases affect millions of people across the globe, and their treatment is often not easy, as most current therapies can cause adverse effects on patients. The overarching goal of our research is to improve our understanding of the monoamine neuromodulation network in *C. elegans* via development of a computational representation of the network. With this insight, therapeutic strategies for a number of diseases can be enhanced.

The objective of this project is to generate a transgenic strain of *C. elegans* with a DNA-encoded protein sensor for dopamine molecules. The so-called GRAB-DA sensor changes its fluorescence upon binding with dopamine. Using the Gibson assembly protocol, we constructed a plasmid that encodes expression of GRAB-DA in all neurons. We transformed bacterial cells with the constructed plasmid and extracted DNA to increase the plasmid concentration. We have sent the plasmid for sequencing to confirm its assembly.

Upon verification of our plasmid assembly, we will inject it to nematodes to induce transgenic expression. Once this is complete, we will begin imaging the nematodes and the levels of dopamine as they starve over a two-hour period. Additionally, the GRAB-DA plasmid assembly will set the stage for assembling the next GRAB plasmid - one for serotonin.

Which Neurons Express the Membrane-Bound SMP-1 in the *C. Elegans* Ventral Nerve Cord?

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Neurons are critical cells that allow for communication between the brain and the body yet are extremely fragile and can be easily damaged during injury due to excessive pressure, stretching, or cutting. Such damage prevents neurons from transmitting signals to and from the brain, leading to a loss of function of muscles. Despite the significant role neurons play in carrying out every action of the human body, nerve growth and repair (neuronal regeneration) after injury is very limited in the mammalian nervous system and not well understood. Without neuronal regeneration following injury, diseases are likely to develop. Successful regeneration will benefit many human diseases such as spinal cord injury, traumatic brain injury, glaucoma, and neurodegenerative diseases.

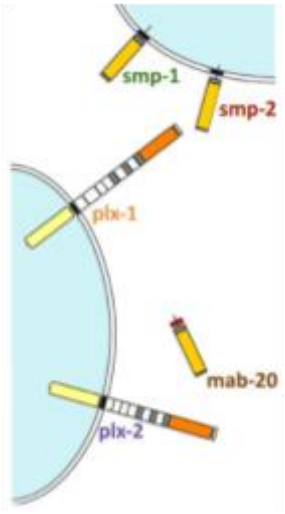

Figure: In *C. elegans*, semaphorin 1 and 2 are transmembrane proteins whereas mab-20 is secreted and diffused.
Adapted from https://www.biorxiv.org/content/10.1101/2021.11.13.468479v1

Since testing such matters on humans is complicated, we use a model organism: *C. elegans*. One important feature shared between *C. elegans* and humans is the semaphorin-plexin signaling pathway, which is known to be involved in regeneration in *C. elegans*. The reason it is easier to test on *C. elegans* is because its genome encodes for 3 semaphorin proteins and 2 plexin receptors compared to the 20 semaphorins and 9 plexins in the mammalian nervous system. My project specifically focuses on semaphorin-1, also known as SMP-1 and its receptor PLX-1.

To identify specific locations of semaphorin-1 activity, I am generating transgenic animals that are fluorescently tagged using GFP. This is being done by creating a plasmid that expresses the SMP-1 gene and transforming it in bacterial cells to grow many copies of the plasmid. The plasmid is then injected into *C. elegans* organisms using an injection microscope. The GFP will then be expressed in any cell that transcribes the SMP-1 gene. The next step will be to use the NeuroPAL identification map to identify which neurons or other cells express SMP-1 in the ventral nerve cord. NeuroPAL is a novel strain of animal which allows for precise identification of individual neurons by expressing different fluorescent markers in each neuron.

By continuing with this research I will be able to better the understanding of semaphorin pathway signaling by determining the cellular location of SMP-1 and its signaling partner PLX-1. By applying the results of my experiments to the very similar semaphorin-signaling pathway in humans, I hope to be able to provide insight to new therapeutic approaches that haven't been considered yet regarding regeneration in the central nervous system.

Assessing Subject Motion in Task-based and Resting-state fMRI Scans

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Functional Magnetic Resonance Imaging provides researchers and clinicians with the ability to diagnose, treat, and learn more about neurological disorders and overall brain function. Due to head motion, up to fifty percent of scans, especially from pediatric and clinical subjects, yield inconclusive results, causing a considerable waste of time, money, and resources. In order to increase the efficiency of fMRI and aid the progression of neurological research, fMRI data was accessed from the Cambridge Centre for Ageing Neuroscience (CamCAN) database and preprocessed using Statistical Parametric Mapping, a popular software package for analyzing data. Data from three scans were downloaded: resting state, movie watching, and sensorimotor task. First, all of the volumes of a single subject's fMRI scan were realigned to the first image in an attempt for motion reversal. The amount of motion experienced was quantified using a framewise displacement formula, which shows translational motion in millimeters and rotational motion in degrees of each subject. The framewise displacement was calculated for each type of fMRI scan and compared by age and gender to find that subjects experience less motion while movie watching and older subjects experience more motion than younger subjects. We also found that the framewise displacement increased as the scan progressed, and in the movie scan, motion was greater during scene changes, dialogue, action, and suspense. The framewise displacement was also calculated for each motion axis: x, y, and z translation and roll, pitch, and yaw rotation to find that throughout all scans, participants experienced greater motion in the y, z, and pitch axes. This is characteristic of head nodding. Using these findings, approaches can be taken to improve the quality of fMRI scans including head molds, movies catered to decrease motion, and better correction for motion in statistical analysis. In the future, I would like to analyze head motion in patients with neurological disorders such as autism and schizophrenia.

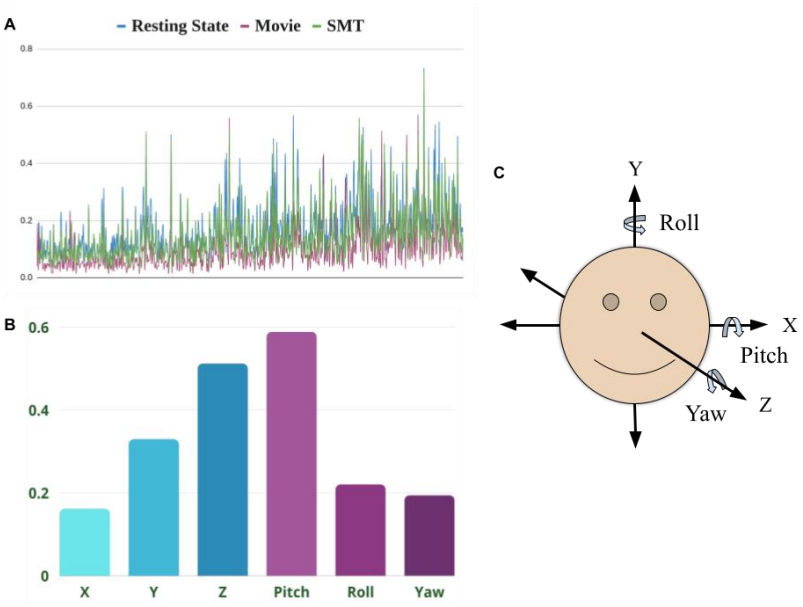

Figure #1: A. A depiction of the translational framewise displacement in the three fMRI scans: resting state, movie, and SMT. **B.** A breakdown of the framewise displacement in the six axes of motion **C.** A visual of the different axes of translation and rotational movement.

Development of a Portable and Inexpensive Research Grade Force Plate Apparatus Utilizing a Nintendo Wii Balance Board

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Abstract: The oculomotor (visual) and vestibular (balance) systems are two of the systems impaired during a concussion. Existing concussion screening lacks repeatability and objectivity between clinicians. Currently, quantifying the deficiencies of the vestibular system requires research-grade force plates that cost in the tens of thousands of dollars. A more affordable system is necessary for an eventual concussion detection platform that can be utilized on a consumer scale. This projects aim to create substitute research-grade force plates using a Nintendo Wii Balance board. To test the efficacy of the device that will be developed in this project, we will replicate a study that has been conducted in the Sensorimotor Quantification and Rehabilitation Laboratory (SQRLab) utilizing research-grade force plates to investigate the interconnectivity of the vestibular and oculomotor systems. The study procedure included participants standing on stationary force plates while performing various different eye movement tasks. The study utilized the OculoMotor and Vestibular Endurance Screening (MoVES) protocol while the participants were standing on the force plates. The force plates tracked their center of pressure (balance) and showed the difference in posture and balance while doing the different eye movement endurance testing. This idea came from Dr. Chang Yaramothu when he wanted to expand the previous study, but was limited by the device. The device being the research-grade force plates, these force plates were not portable and were very expensive, which was not cohesive with the goals he had. Dr. Chang Yaramothu saw that other labs had used a Nintendo Wii board as force plates and wanted to know if it would work for the SQRLab.

We hypothesized that the data collected from the Wii Board would be able to be analyzed with an accuracy of >85%. The accuracy is tracked by comparing the data collected from the Wii board to the research-grade force plates. Due to the WiiBboard not being created for accuracy and analysis of its data, the study focused on adapting the Wii Board's output data to analyze proficiency. We used the application MATLAB to transfer the data from the board and filter through the inaccuracy. It was necessary to filter through the data if we wanted to run it through the existing code used for the research-grade force plate control study. The data outputted from the application were: Time in milliseconds elapsed since the program was opened, Forces from all four sensors in kilograms, COP distance from the center in both x and y directions. and total force in kilograms. The data that is used in the analysis of the vestibular system is the COP distance since it tracts the balance of the user.

The Effect of Sound on Dendritic Morphology at Developmental and Evolutionary Timescales

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One in five people receives treatment for mental illness in the United States. There is a lack of understanding at the cellular and molecular level of why this phenomenon and other maladaptive behaviors persistent through natural selection. I studied neuronal maladaptation in the fish *Astyanax mexicanus* (Fig. 1) as a model system. *Astyanax* is especially suitable as it is extant in two morphologically different forms: one ancestral and other derived populations. Furthermore, there is evidence that the visual dendrite in the large decision-making Mauthner neuron is sensitive to the absence of visual stimuli during development. I studied the development of the auditory dendrite to the lack of input. I predict that the auditory dendrite will also be developmentally malleable because the soundscape of the new environment is different from the ancestral environment.

I aimed to observe the morphological variability of the lateral dendrite of the Mauthner neuron that has either been reared in an anechoic chamber or in a noisy chamber along with a control group. In addition to the noisy and anechoic chamber, an ear ablation condition was also designed to provide information about the integration of auditory stimuli in the absence of the primary auditory sensing organ. The anechoic chamber served as a sensory deprivation condition whereas the noisy chamber contrastingly provided a positive stimulus condition using white noise or randomly generated clicks as the larvae developed (Fig. 2).

I plan to image Mauthner neurons via laser scanning confocal microscope and then quantify the morphological changes observed with respect to the lateral dendrites. The results of my work will indicate whether neuronal maladaptation is specific to one of the dendrites, which equates to one sensory modality over the other, or perhaps both, indicating that the entire Mauthner neuron is subject to maladaptation.

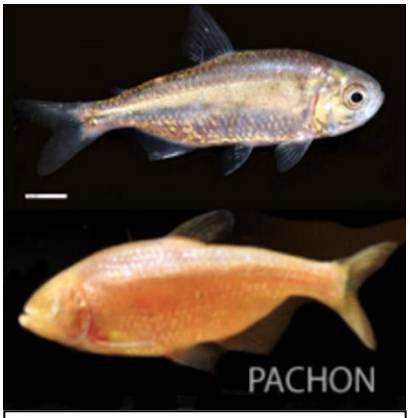

Figure 1. *Astyanax mexicanus* is extant in two forms. Ancestral surface fish (top) the lives in rivers, and derived cavefish (bottom) from

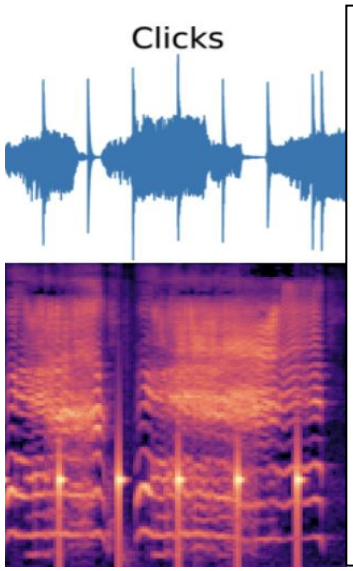

Figure 2. The sound stimulus can be quantified in the lab to control frequency and amplitude. Here, with clicks stimulus as an example, the speaker output (top) and corresponding spectrogram (bottom) can be seen to match over time. The random placement of high-power clicks composed of multiple frequencies prevent the fish from habituating.

3D Bioprinting of Soft Tissue Sarcoma Spheroids-Laden GelMA for Tumor Modeling

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Abstract: Bioprinted hydrogel-based microfluidic models are suspected to be able to mimic the cellular composition of the extracellular matrix properties in that of tumor tissue. The completion of this study can lead to the development of personalized medicine through rapid drug screening. With personalized medicine, the risk of adverse effects as it relates to cancer treatments can be limited seeing as how the drugs will have the ability to target the abnormal cells while leaving the unwarranted cells alone. Whereas, in current cancer drug screenings, the only way to test the effectiveness and dosage is to directly deliver the medication to a living organism. This method can lead to both inhumane practices and minacious health developments. The 3D Bioprinted Microfluidic Chips approach will grant medical practitioners the ability to harvest the cancerous cells from their patients and structure a device that allows researchers to understand how the medication or treatment will directly affect them without bringing about any unwarranted complications. The methodology of the experiment is to form spheroids in low attachment plates and then encapsulate them in uncrosslinked 5% GelMA hydrogels. After UV Crosslinking through a light-based bioprinting technique and bioprinted spheroid-laden GelMA on a glass slide, we then observe the cell behavior for 14 days while they're still in the GelMA chip. Cancerous cells have known hallmarks that allow them to continuously divide. In order, for this study to be successful, the cancer cells ought to be able to replicate these same hallmarks inside of the chip. Careful monitoring of the hallmarks drives a large portion of the experiment. Seeding the Soft Tissue Sarcoma allows for one to track their behavior for the frequent hallmarks of migration and metastasis as well as others. As expected, in the presence of a protein-rich serum buffer the cell spheroids were viable on the periphery, and they formed a hypoxic core similar to in-vivo conditions. Therefore, this rendered the Gelatin Methacrylate of being capable of providing a biomimicking Extracellular Matrix. Future work will include assessing the Ki-67 expression of Soft Tissue Sarcoma spheroids with and without the presence of fibroblast and to deliver the drug NVP-TAE684 to detect and examine how cell migration and metastasis anticancer properties are affected on a tumor and it's microenvironment.

Phonon Propagation in Enzymes

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Abstract: The purpose of this experiment is to create a model for phonon propagation in enzymes. When enzymes catalyze a reaction, they produce heat which is then diffused throughout the protein as phonons. The way in these phonons propagate throughout the enzymes can have large impacts on the proteins' structure such has unfolding of the secondary and tertiary structures or even full denaturation. The current literature surrounding the topic has shown that phonons propagate mostly through hydrogen bonds which make up the secondary structure of proteins. For this experiment, the phonon propagations are simulated using both computational and experimental means. The computational one can provide the resonant frequencies at which edge modes exists. The experimental simulation is done by constructing a mechanical model of the enzyme TrpZip2 out of magnetic fidget spinners. Phonons are sent through it using an actuator and frequency generator then the movement of specific spinners are measured using an accelerometer. Overall, four pathways were tested each with a specific starting spinner and an ending spinner (called the actuated and measured spinners, respectively). These results from the experimental one can be graphed along with the resonant frequencies from the computation simulation to determine if the resonant frequencies match with the experimental data; an example is shown in Fig 1. Overall, the data showed that hydrogen bonds had much more movement than the carbon backbone which agrees with computer simulations and literature reviewed. Additionally, the hydrogen bonds had more peaks correspond with the resonant frequencies. This means that the reason hydrogen bonds are better for phonon propagation is because they have more edge modes, frequencies at which conduction can occur inside a band gap. Future work will involve using this knowledge to control pathways so that they may be used in practical applications.

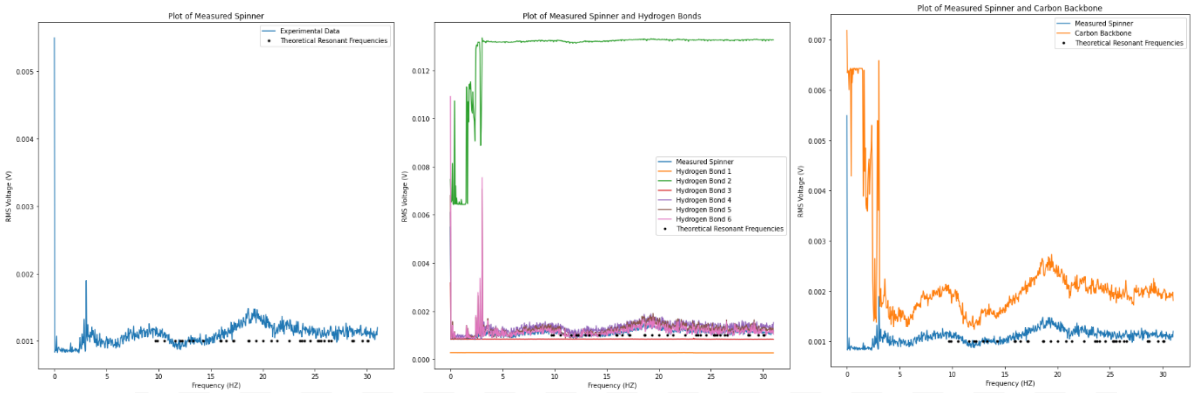

Figure 1: An example of the results obtained from the mechanical model plotted with the resonant frequencies obtained from the computational simulation. For all plots, the x-axis is the frequency of phonons in hertz while the y-axis is the motion of the spinner in RMS Voltage in volts. The black dots on each plot represent the resonant frequencies obtained from the computational simulations. The left most plot is the measured spinner. The middle plot is the measured spinner along with the spinners of the hydrogen bond. The right plot is the measured spinner with the carbon backbone spinner. It can be seen from the second plot that on one of hydrogen bonds (Hydrogen Bond 1) is much more active than the rest of the hydrogen bonds as well as the carbon backbone in the right plot. Furthermore, more of the peaks in graphs of the middle plot align with the resonant frequencies compared to the carbon backbone in the right plot indicating that the hydrogen bonds have more edge modes.

Using Deep Hybrid Modeling to Identify Biophysical Mechanisms Underlying Circadian Rhythms in Cardiac Arrhythmias

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Electrical activity in the heart exhibits 24-hour rhythmicity, with sudden cardiac death more likely to occur in the morning than at other times of the day. Our daily activities and physiology are regulated by an internal biological clock known as the circadian clock. Studying how the circadian clock affects cardiac electrophysiology may give us a better understanding of why potentially fatal cardiac arrhythmias are more likely to occur at certain times of the day. Electrocardiogram (ECG) recordings are used to evaluate the heart's functionality. Hayter et al. developed MATLAB functions to analyze human ECG recordings and extract features such as the QT interval (see Figure 1). They observed day/night differences in these feature values. We hypothesize that the circadian variation in these ECG features can be explained by circadian rhythms in cardiac ion channel conductances. Our goal is to explore the relationship between ion channel conductances and ECG features using a Deep Hybrid Model that combines mechanistic modeling with deep learning. Our mechanistic model is a set of ordinary differential equations (ODEs) that simulate cardiac action potentials and our deep learning approach involves conditional Generative Adversarial Networks (cGANs). We used the DeepHM software package provided by IBM Research to create an inverse surrogate model trained to identify the conductance parameter regions of the mechanistic model that correspond to the distribution of QT intervals extracted from the original data. Then by providing QT intervals recorded during the day and at night for a given patient we can check how the cGAN maps these feature values to parameter space and learn how certain ion channel conductances are changing across the circadian cycle.

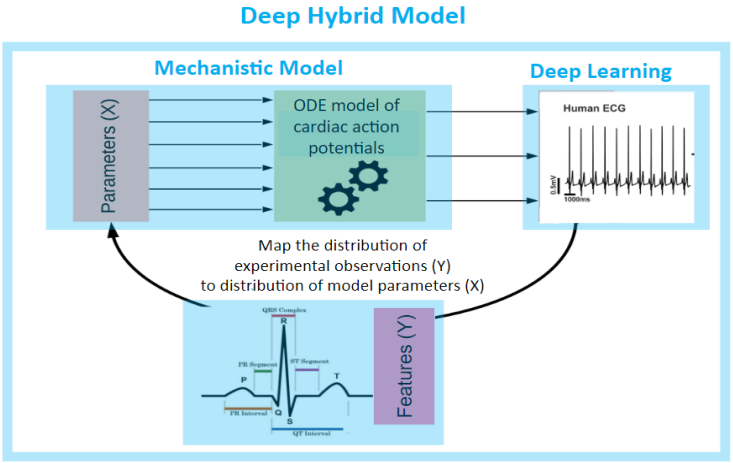

Figure 1: Deep Hybrid Modeling process for studying the effect of circadian rhythms in cardiac ion channel conductances on ECG features.

Curing Madness: Ottoman Psychiatric Treatments in the 19th Century

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Abstract: Ottoman psychiatric care spanned six centuries and encompassed a variety of different treatments and procedures. However, their approaches are severely understudied. Examining medical history is extremely beneficial as it provides insight into the origins of present-day medicine. Furthermore, with the field of psychiatry on the rise, the demand for research and historical insight on treatments and diagnoses is increasing. In the 19th century, as the need for proper care for the mentally ill grew, the Ottomans focused their efforts on remodeling existing medical institutions and adapting them for psychiatric care. The approaches that the Ottomans took to relieve their patients were up to par with the contemporary state of psychiatry at the time. Treatments included: hydrotherapy, music therapy, aromatherapy, color therapy, herbs, and medications. This research explored these remedies and analyzed their purpose, prevalence, position in medicine and society, and impact on modern-day medicine. After completing a comprehensive literature review that sourced records written in English, Turkish, French, and Ottoman, we compiled the findings into an online historical database using Scalar– an open-source digital publication platform. Our results showed that certain therapies were more common than others. For example, records indicate that the Ottomans heavily utilized hydrotherapy. In fact, most insane asylums during the time contained rooms dedicated to hydrotherapy. In addition, we found that most of these treatments are still in practice today in different parts of the world. Nonetheless, this project worked to show how these regimens were a key component of the Ottoman psychiatric care system. Future research will trace these therapies into the present day, analyze the continuities and changes in medical theory and practice, and formulate directions for how they can be incorporated in treatment plans.

Figure: A new ward in the Toptaşı Asylum located in Istanbul, Turkey. Source: Osman Nuri Ergin, Müessesat-ı Hayriye-yi Sıhhiye Müdiriyeti (Direction Generale de l'Assistance Publique de Costantinople), Istanbul: Matbaa-yı Arşak Garoyan, 1911.

Predicting Vapor Supersaturation in a Laminar Flow for Atmospheric Aerosol Processing

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Atmospheric aerosols have significant climate impacts, which are altered when aerosol particles change their size, composition, or morphology. A major process for such changes is driven by vapor condensation. To investigate vapor condensation in laboratory experiments, a "saturator-condenser" technique is commonly used, where the aerosol flow is saturated with vapor in a warm saturator and then enters a cold condenser. As temperature of the gas drops, vapor becomes supersaturated and condenses on aerosol particles, making them grow. The amount of condensate can be determined experimentally by measuring particle mass or size. However, some volatile condensates rapidly evaporate off the particles, making accurate experimental measurement impossible. In such cases, calculations can be used to estimate the amount of condensate theoretically, which requires the knowledge of the partial pressure and supersaturation of condensing vapor. My goal is to develop and implement a numerical model allowing to predict these two system parameters and evaluate the particle growth rate. Model development will be complemented with experimental measurements to initialize the model parameters and validate its accuracy. This work is a natural extension of my last summer's research project and is needed to complete and submit a journal article on atmospheric impacts of soot aerosols.

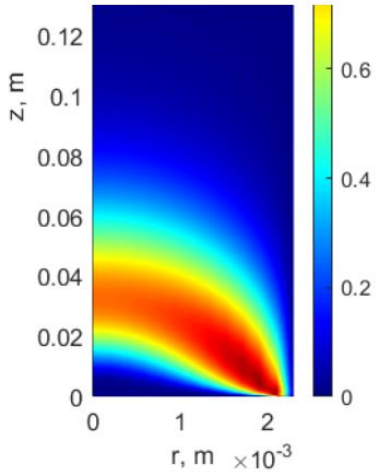

Figure 1: Supersaturation of water in a cooled laminar flow

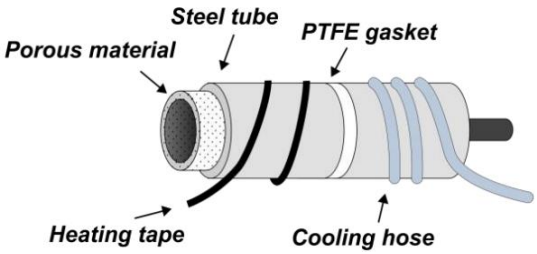

Figure 2: Proposed growth tube

Electron Heating at the Earth's Bow Shock

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Abstract: Bow shock is caused due to the braking of the solar wind flow by the Earth's magnetosphere, and an increase in the temperature of electrons is observed across the bow shock. The bow shock consists of two regions: the upstream region characterized by lower electron temperature, high bulk speed, and low electron number density, and the downstream region characterized by higher temperatures, low bulk speed, and high electron number density. Studying electron heating at the Earth's bow shock is important for our understanding of the near Earth plasma environment and space weather. This study seeks to investigate the correlations between upstream and downstream plasma parameters of the bow shock and the electron heating across the bow shock.

A total of 117 bow shock crossings were selected and the data for electron and ion temperature, bulk speed, magnetic field, and number density for every shock was collected from the MMS (Magnetospheric Multiscale Mission) satellites. For these shock crossing events, the upstream and downstream regions of the shock were identified automatically using ramp (shock) durations. Different plasma parameters were calculated for the upstream and downstream regions, including electron temperature, bulk velocity, electron and ion densities, shock normal and angle. A database containing the averaged parameters and their variations was created. Correlations between different parameters and the electron heating was studied. The best correlation was found to be with the decrease of the flow energy (difference in squared bulk velocities between downstream and upstream regions of the shock). The linear correlation coefficient was 0.8. Our results also indicate that heating can more efficient for more oblique shocks, with shock angle around 90 degrees. While we observed no correlation between the heating and shock angles overall, the strong heating was seen only for shock angles close to 90 degrees. The database will be extended to include more shocks. In the future, the correlations between electron heating and other shock parameters, such as Mach numbers and shock ramp widths will be investigated.

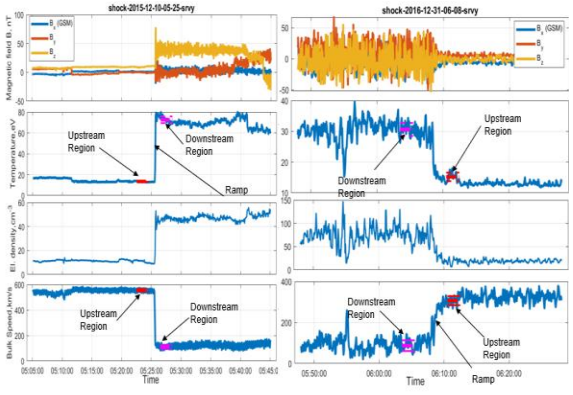

Figure 1: Two examples of the 51 bow shock crossing plots created. Solid red and magenta lines represent averaged parameters, and dotted lines represent variations over the upstream and downstream regions respectively.

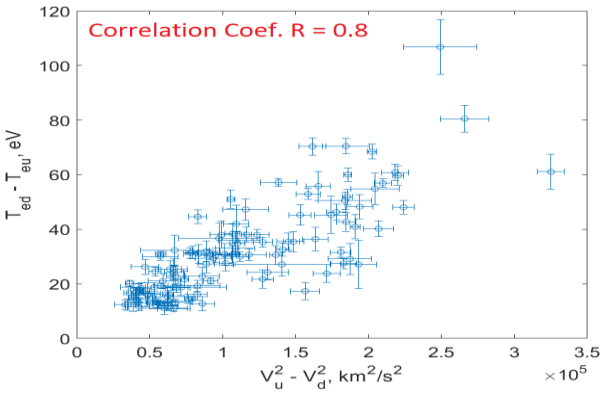

Figure 2: Shows the correlation between electron heating and solar wind deceleration

Electrochemical Stability of Ruthenium Polypyridyl Phosphonic Acid Complexes

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Abstract: Nowadays, dye sensitized solar cells (DSSCs) are used for the conversion of sunlight into energy. One variety of solar cells involves metal oxides, such as indium-doped tin oxide (ITO) and various ruthenium complexes. The focus of this project is to test the electrochemical longevity of different ruthenium complexes in different electrolytic solutions. Four ruthenium complexes were synthesized. Two of the three ligands on each complex were the same, while the third ligand varied. The ligand that stayed the same for the four complexes was bis(phosphonic acid)-bipyridine, used twice for each complex. The third ligand varied from bis(phosphonic acid)-bipyridine to phenanthroline, dibromobipyridine, and bipyridine. Small strips of conductive glass were plated with one of the four ruthenium complexes, and cyclic voltammetry was run using these plated glass strips as the working electrodes. Each experiment had 200 sweeps from 0 to 1.5 V with a rate of 0.01 V/s. The solutions tested were 0.1M KNO_3 in 0.01M acetate buffer, 0.1M $NaBF_4$ in 0.01M acetate buffer, 0.1M KNO_3, and 0.1M $NaBF_4$. It was found that the unbuffered solutions produced higher longevity of the electrodes. Additionally, it was found that the complex with three bis(phosphonic acid)-bipyridine ligands to have a higher longevity than the remainder of the complexes. Further research can be conducted with different ruthenium complexes and with different electrolytic solutions.

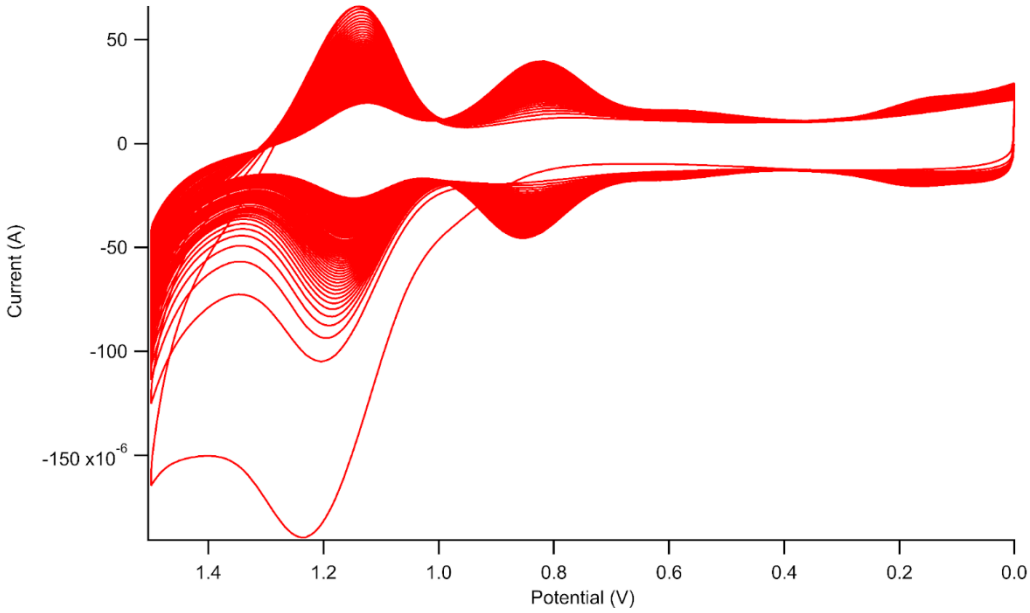

Figure 1: Cyclic Voltammetry Spectrum of a Ruthenium Complex-Plated Electrode in an Electrolytic Solution

Microplastics as Hubs Enriching Antibiotic-Resistant Bacteria and Pathogens in Anaerobic Sludge

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Microplastics can stimulate the growth of antibiotic-resistant bacteria (ARB), which poses risks for human health and natural biota. Wastewater treatment plants (WWTPs), specifically anaerobic sludge digestion units, can serve as "hot spots" where microplastics, antibiotics, and antibiotic-resistant bacteria coexist. In this study, anaerobic sludge microcosms were prepared using anaerobic sludge from a New Jersey WWTP, polystyrene (PS) and polyethylene (PE) microparticles as representative microplastics, and sand microparticles as a control. Sand, PS, and PE treatments were prepared in triplicate with and without sulfamethoxazole (SMX), a sulfonamide antibiotic. Microscopy was used to visualize the formation of biofilms on the microparticles. Additionally, qPCR was used to quantify sulfonamide resistance genes (*sul1* and *sul2*) and the co-occurring mobile genetic element (*intI1*) present in the biofilms. Thus far, our research has shown that significant growth of biofilm on microplastics occurs by 8 days. Furthermore, we hypothesize that PS and PE will show significant enrichment of *sul1*, *sul2*, and *intI1* as compared to sand. We also hypothesize that microcosms with SMX will show even higher enrichment of the aforementioned genes. Such results would imply the ability of microplastics to directly enhance the abundance of ARB in anaerobic units of WWTPs. Given that the digestate left after anaerobic digestion is often repurposed into fertilizer, the escape of microplastics or ARB from WWTPs into natural systems could adversely affect human health. Future work could include 16s rRNA amplicon sequencing to identify the specific bacterial species present in the biofilms, or metagenomic sequencing to study the functions of the microbial communities in such microcosms.

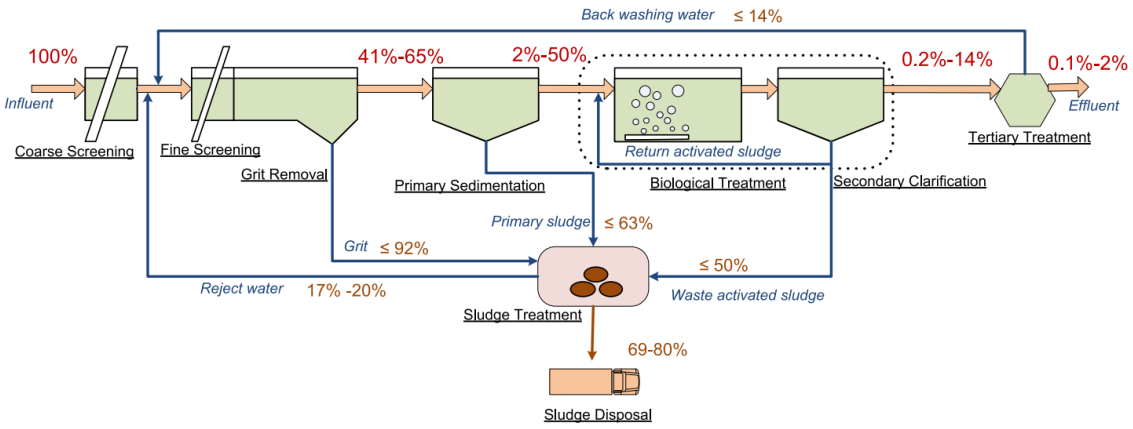

Figure 1: Microplastics particle flow in a wastewater treatment plant (Sun et al.)

References:
Sun, Jing, Xiaohu Dai, Qilin Wang, Mark CM van Loosdrecht, and Bing-Jie Ni. "Microplastics in wastewater treatment plants: Detection, occurrence and removal." Water research 152 (2019): 21-37.

Water Quality of Branch Brook Lake and Weequahic Lake

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Water quality is defined as the goals or standards that must be achieved by a water body under the regulations of the Environmental Protection Agency (EPA) to designate their use and serve the purpose of the Clean Water Act (EPA, 2022). Water quality reports are crucial procedures for the preservation of fresh water and the identification of its pollutants commonly caused by human activities. These reports can help identify and control the risk that pollution can generate to public health and the environment. Once the pollutants are identified, their concentrations can be controlled potentially by first identifying point and non-point sources of pollution and then implementing solutions such as stormwater management practices. The water quality parameters of Branch Brook Lake and Weequahic Lake, both located in Newark NJ, were studied in the summer of 2022, following the standards stated by the EPA. The parameters extensively measured include pH, temperature, conductivity, salinity, hardness, alkalinity, total phosphorus, nitrates, chlorides, ammonia, dissolved oxygen, turbidity, and total solids. Both lakes presented turbidity levels above 5 NTUs required for drinking water but lower than the maximum 50 NTUs for lakes and ponds (EPA, 2014). The level of total phosphorus for both lakes in all the samples evaluated was higher than the maximum of 0.05 mg/L (EPA, 1986). Levels over the recommended threshold can cause algae blooms which can produce toxins harmful to humans as well as reduce the dissolved oxygen in the water which can endanger wildlife. All the other parameters met the standards required by the EPA. Future research will focus on locating the point and non-point sources of pollution for both lakes, stormwater management and their hydrology.

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Controlling Madness: Constructing Space and Time for Toptaşı Asylum's Staff

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Abstract: The Ottoman Empire's history of psychiatric power appears only briefly in Western accounts partly due to the disregard for non-Western histories. Without adequate documentation and accessibility in this field, modern psychiatry lacks narratives of non-Western experiences which inhibits it from reaching its full potential. While some Western societies built purpose-built elaborate designs for psychiatric institutions on which history of psychiatry focused, the Ottoman Empire conducted its treatment of the insane in repurposed spaces. This research proposes to include asylum's staff, both medicinal and administrative members, to better understand the power structure in Ottoman psychiatric institutions. To better analyze the complex power structure, this research sought to bring about a simulation of a typical day in the Ottoman Empire's public asylum within the gaming platform Unity. By translating primary documents from Ottoman Turkish, the daily routines of Toptaşı's staff were compiled into itineraries for agent-based modeling. Within SpatioScholar, the Unity project, this research added a select group of the staff as agents to the existing simulation of patients and doctors. These agent additions, 19 in total, were 2 physician assistants, 4 nurses/caretakers, and 13 custodians. The simulation's results indicate that the custodians, the lowest level of the medicinal hierarchical structure, had the most daily power over the patients. Custodians were responsible for patients at every time of the day, and in every space. Future work for this project would focus on adding every level of staff and the men's ward to the simulation. By having a complete simulation, one could see how the entire asylum functions similar to contemporary medical facilities. Both historical and contemporary accounts would benefit from giving agency to the members of staff at varying hierarchical levels, especially those traditionally left out.

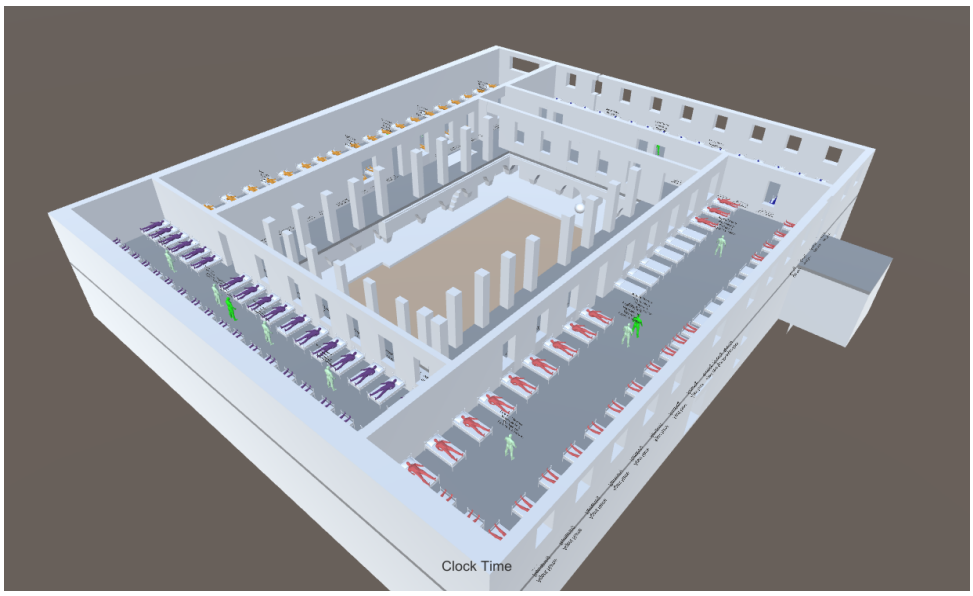

Figure #1: SpatioScholar rendering of Toptaşı Asylum's women ward. Contains 138 agents.

Reflections on Rocks
Conceptualizing the James Rose Center Digital Archive

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James Rose is one of the mavericks of modern landscape architectural design, known for pushing the field into the modern age in the middle of the twentieth century. However, Rose's work remains under-studied mainly due to his individualistic nature, his unorthodox design method, and scholars' limited access to view his professional records. This ongoing project aims to explore the creation of a digital archive of Rose's work, all of which is currently housed physically in the James Rose Center in Ridgewood, NJ (Rose's previous home and studio). This phase of the project concentrates on the conceptual narrative of an archive for a designer like Rose, who practiced an intuitive, hands-on approach to landscape architecture, leaving very little physical records of his built spaces. Because of the nature of his work, a traditional architectural archive of drawings and photographs would simply be ineffective and create an incomplete picture of Rose's practice for scholars attempting to study him. Instead, an effective archive would show not only Rose's completed works, but reveal his process as well.

In the first track of this project, I visited other iconic houses of architects which have been converted to research centers and museums to learn more about the technical requirements of creating an archive within the building the archive is referencing.

To conceptualize the creation of this archive, I acted as Rose would - with spontaneity and intuition. I explored the house and his belongings without preconceived notions, focusing on the most basic element of the built environment - rocks - to begin to understand Rose's creative process. Narrowing my field of focus to one element allowed me to view it holistically, and begin to understand which elements of his built works and both professional and personal belongings needed to be contained in an archive, and how they needed to be presented, in order to give a complete picture of Rose.

Rose's work brings a new meaning to interdisciplinary, taking architecture beyond the confines of the built space to writing, art, theater, travel, social commentary, and immaterial ideas of his own and of the people around him. An archive for Rose must be able to present these connecting physical elements, not as individual pieces, but as a collage, in order to adequately reveal his process as an artist. The resulting interactive, discoverable, physical collage for the Reflections on Rocks created this summer reveals how a single architectural element, such as rocks, can be influenced by an array of interconnected architectural themes and ideas. The collage shows how the archive must celebrate the layers of his work, rather than attempting to strip them away through a rigid hierarchy.

The Secularization of Italy and Prevalence of Vernacular Devotion

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Historically, religion has been a key factor in how people form communities and values. Over the last few decades, religious practice has declined in Europe and North America. Studies indicate that this trend is observed in Italy as well; albeit, more slowly than elsewhere in Europe. If religious practice and affiliation is declining as current studies indicate, then understanding how and why its happening is vital to the research of how communities are changing today.

The goal of this project was to analyze the trend of religious practice in Italy by transcribing and developing a database of the votives surrounding the shrine to the Madonna degli Orfani (Rome, Italy) based on the annual documentation of devotional activity at the shrine over the last 7 years. These transcriptions made use of the photos of the shrine that capture its nearly 400 votive plaques. My transcriptions of the 2021 and 2022 votives were combined with five previous years of transcriptions in a database of approximately 2000 entries, analyzable by date, physical feature, and content. These votives offer a view of devotional practice that is distinct from the self-reported church attendance sociologists of religion typically use as a measure.

Considering the past seven years, I compared the number of dated votives each year to that of church attendance and found that there was a slight upwards trend in devotion at the shrine. Self-reported church attendance, by contrast, has been declining since 1968, and at an average annual decline of .5% of the population between 2011 and 2020. I also found that there were particular years when there were significantly more dated votives. I attempted hypothetical explanations for these spikes in devotion by studying actions by Pope Francis and his predecessors, as well as significant world events. When observing all votives, not just those with a date, the total number of votives remained constant at around 400 since 2018, however there was a sharp increase in votives between 2016 and 2018. This increase follows what appears to be some maintenance to the shrine, replacing a glass panel protecting the Madonna, and refurbishments. This supports the finding that vernacular devotion at this shrine has increased, or at the very least is persistent despite falling church attendance.

The shrine is being maintained and preserved, and devotion appears to be increasing despite declining church attendance. For future work, more research into the factors affecting devotion at this shrine to normalize the data should be done in order to better represent religious devotion throughout Italy.

1,4 -Dioxane Degrading Propanotrophs Capable of Degrading Cooccurring Inhibitory Chlorinated Solvents

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Enlisted by the U.S. Environmental Protection Agency (EPA) as a contaminant of emerging concern, 1,4-dioxane is a synthetic chemical that has historically been used as a stabilizing agent for chlorinated solvents, – 1,1,1-trichlorothane (TCA) in particular. As a consequence of accidental solvent spills coupled with improper disposal of industrial waste, dioxane has been released into the environment as a widespread and prominent groundwater contaminant. During the third round of the Unregulated Contaminant Monitoring Rule (UCRM3) program, dioxane was detected in groundwater from releases at hazardous waste sites across the United States. Classified by the EPA as a probable human carcinogen by all routes of exposure, it has been reported that short term exposure to dioxane may cause eye, nose, and throat irritation; and long-term exposure may cause kidney and liver damage. Owing to its extreme hydrophilicity and the stability of its heterocyclic structure with two ethers linkages, dioxane has proven to be recalcitrant to most physical and chemical groundwater remediation technologies (for example, in-well air stripping or air sparging, thermal destruction technologies, and traditional pump and treat systems), rendering them inefficient for dioxane remediation. Other chemical treatment technologies like advance oxidation processes (AOP) and granular activated carbon (GAC) are commonly employed instead. However, these technologies are usually costly taking into consideration the energy requirement as well as the treatment duration. Alternatively, in situ bioremediation is an attractive method which requires comparatively low-energy and low-cost for effective remediation of dioxane removal from groundwater in addition to its eco-friendliness, being less destructive to polluted sites during operation. Nevertheless, challenges associated with implementing in situ bioremediation technologies for dioxane arises from the fact that dioxane contaminated aquifers are typically impacted with chlorinated solvent mixtures as well, a consequence of the historical usage of dioxane as a stabilizer for chlorinated solvents. The presence of chlorinated solvents has been reported to inhibit the bacterial enzymes involved in the biodegradation of dioxane. Thus, the removal of these chlorinated aliphatic hydrocarbons (CAHs) is prerequisite to employing suitable bioremediation technologies. In this study, we analyzed the ability of two microbial cultures to degrade and overcome the presence of the most inhibitory of the many cooccurring chlorinated solvents at dioxane contaminated sites: 1,1-dichloroethene (DCE) and trichloroethene (TCE). Two propanotrophic dioxane cometabolizers were employed, *Mycobacterium* sp. DT1 and *Azoarcus* sp. DD4. DT1 was observed to concurrently remove dioxane and TCE, while DD4 was observed to synchronically remove 1,1-DCE with dioxane, both when amended with propane as the main carbon source. This was uncovered combining the use of microbial culturing techniques, in addition to chemical analytical techniques like GC/FID to monitor the growth of the microbes in addition to the consumption of dioxane, propane, TCE and 1,1-DCE.

Magnetohydrodynamic Simulation on Solar Magnetic Field Eruptions Driven by Small Emerging Flux

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Abstract: Solar flares and coronal mass ejections (CMEs) are the most powerful phenomena in our solar system. Although many observational and theoretical studies have been done so far, their initiating mechanism is still a puzzle. In this study, we investigate a potential triggering mechanism for solar flares and CMEs which is small emerging flux (EMF) that appears at a local area of the solar active region. Since recent observational study (e.g. Wang et al. 2017) have reported sighting of EMF appearing just before the flare, it have been suggested that the EMF can be a strong candidate for the triggering mechanism of solar eruptions. Some studies in the past have successfully produced eruption with EMF in magnetohydrodynamic (MHD) simulations (e.g., Chen & Shibata 2000, Kusano et al. 2012 etc.). However, these simulations have been conducted in 2D space or assuming very simple models in 3D space. In this study, we perform a 3D MHD simulation using a realistic solar coronal magnetic field to better verify the role of EMF as a triggering mechanism in solar eruptions.
First we set the sheared magnetic field lines locally above polarity inverse line (PIL) of the solar active region that is surrounded by the magnetic field which come from the bipole sunspot. This is assumed as pre-flare magnetic field. Next we put the EMF locally at the PIL and compare the dynamics of the magnetic field with EMF or without EMF. In the result, we did not observe the EMF to efficient cause the eruption. In comparison to older studies, our simulation is more realistic and account for an emerging flux that is closer to observation values, and so the results were heavily dependent on initial conditions. Future simulations could be conduct over a wider range of initial conditions, which for example, could include highly twisted magnetic flux rope.

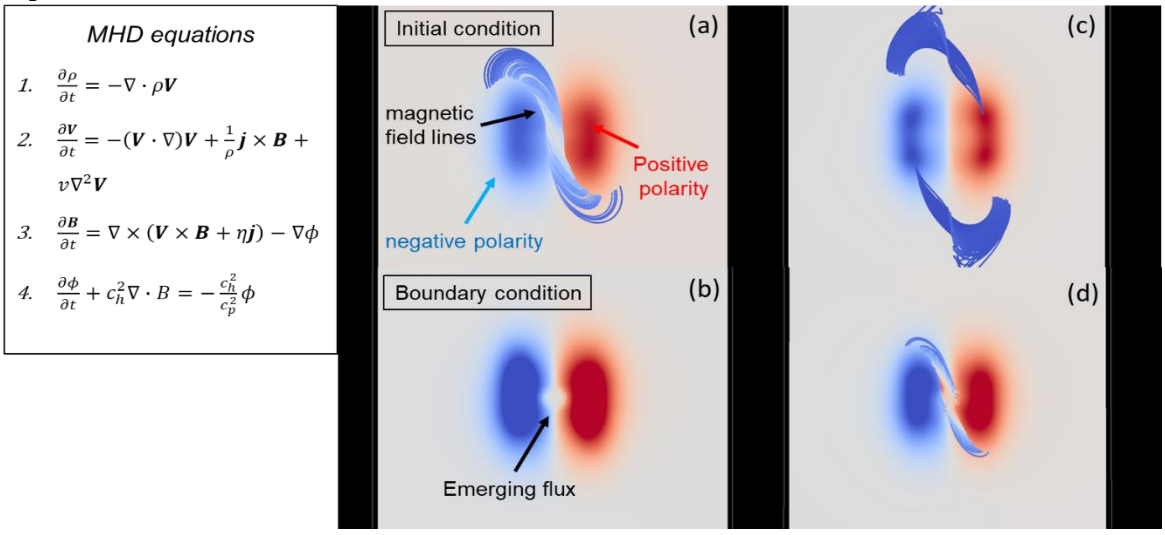

Figure: (a) Initial condition with simple bipole sunspot. (b) Boundary condition with fully formed EMF
(c) Example of erupted magnetic field lines without EMF (d) Example of non-erupted magnetic field lines even with EMF

The Use of NMR to Quantify the Degradation Efficiency of PFAS Using High Frequency Ultrasound

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Often referred to as "forever chemicals", per- and polyfluoroalkyl substances (PFAS) have become widespread in our environment due to the challenge of breaking them down. When exposed to humans, they have the potential to cause birth defects, damage the immune system, and even cancer. One of the ways humans get exposed to PFAS is through drinking water. While there is technology to filter PFAS from drinking water, there is still a need for technology to actually break down those filtered PFAS to prevent them from reentering the environment. The aim of the lab I worked with is to optimize high frequency ultrasound technology for the purpose of degrading PFAS. When the technology is applied, there needs to be a method to analyze the PFAS samples to determine the percentage of degradation that occurred and if PFAS daughter products were formed. This summer the analytical method of NMR spectroscopy was used for this purpose because it performs non-targeted analysis to be able to detect most PFAS due to the shared terminal CF_3 response that most PFAS chemicals share. This characteristic makes NMR more advantageous than other methods which can only detect a select few different PFAS chemicals.

An NMR analysis method and standard operating procedure (SOP) was first created as follows. PFAS contaminated water samples treated with high frequency ultrasound and untreated were collected. Then, using an adapted EPA 1633 method of solid phase extraction (SPE), the samples were concentrated by a factor of 50 because the NMR only detects in high concentration ranges. NMR analysis was performed and the concentration of samples before and after treatment were determined using an established calibration curve and internal standard. A reduction in the PFAS concentration of a sample was correlated with a reduction in the CF_3 response. Additionally, the NMR can be a good indicator of if PFAS daughter products were formed during treatment because then new response peaks would have appeared after treatment. It was found that SPE is a vital part of the sample preparation process for NMR analysis and must be done without error otherwise, low percent recoveries will interfere with the accuracy of NMR results. Future research should investigate using NMR analysis to determine PFAS degradation in PFAS contaminated water samples collected from the field.

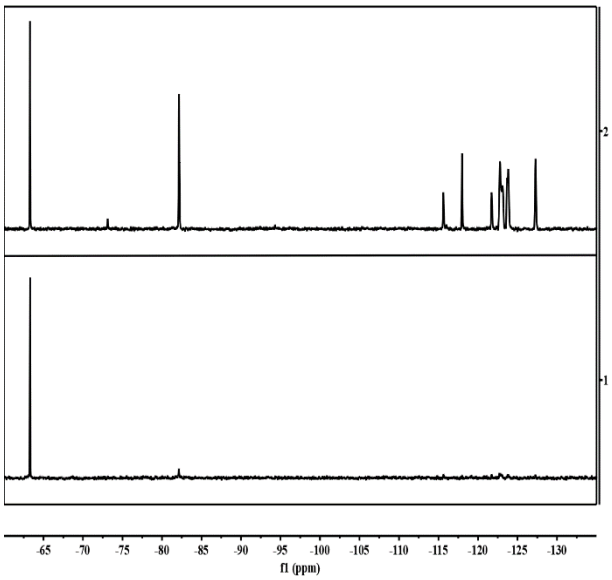

Figure 1: NMR spectra of an untreated PFAS sample (top) and treated PFAS sample (bottom) showing reduction in CF_3 peak (-82 ppm).

Air Quality Monitoring System in the Ironbound

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According to the UN, today, around 55 percent of the world's population live in cities, with that statistic set to increase to 68 percent over the coming decades (The Climate Reality Project, 2017). Since they house a large percentage of the population, global environmental issues pose a significant threat to cities. My research focuses on the city of Newark, New Jersey, where toxic air surrounds the industrial neighborhood of the Ironbound. The Covanta trash incinerator, which burns nearly "2,800 tons of trash each day," along with diesel pollution, caused by outdated trucks, are the main culprits for the abundance of PM2.5 pollution, which causes asthma in 1 in 4 Newark children, 3 times higher than the national average. There is a lack of transparency about local air pollution, resulting in stagnant progress to mitigate this pollution. Residents are not provided information about their own community air quality, and thus, are unable to effectively demand change. Even with this demand, it is hard to pinpoint specific sources of air pollution, without constant field testing, to develop specific solutions.

My goal is to develop a method for real-time air quality monitoring that could be implemented in the Ironbound, to allow residents and policymakers access to clear and accurate air quality information anywhere in the community. The system would consist of low-cost IoT based PM2.5 monitors placed in various locations in the Ironbound connected to a heat map interface displaying real-time air quality information. This summer, I worked with VentureLink to build a minimum viable product (MVP) of the sensor-map system. I built a low cost air monitor using a PM2.5 sensor and esp8266 microcontroller, and programmed it to send data over wifi to IoT Matlab platform ThingSpeak to visualize time-series sensor data. I used HTTP GET to fetch the data from Thingspeak to ArcGIS Online every thirty seconds. Using ArcGIS, I was able to build a real-time heat map displaying the single sensor's location and latest air quality measurement. This prototype can be powered by any building service and connected to a web app or phone app interface displaying the heat map, accessible to the public. By working with residents and other stakeholders, I will build and implement more sensors, design enclosures, and iterate the interface design, enabling residents to make informed decisions about their health and apply pressure to drive policy change regarding air quality.

Figure 1: Heatmap of mock sensor data in the Ironbound

Investigating the Influence of Root and Soil Depth on Ecosystem Response to Drought

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Abstract: Recent episodes of forest die-off across the globe have been strongly linked to climate change, associated with elevated temperature, insect outbreaks and severe drought. Forests that drought stresses tend to be more vulnerable to additional disturbances such as insect outbreaks and wildfire. Thus it is crucial to accurately predict plant water stress and to anticipate plant response to changing climate. However, it remains challenging to reliably estimate plant water stress, in part due to the uncertainties associated with plant rooting depth and soil depth, both of which are extremely difficult to measure yet critical in determining plant water supply. In this study I leveraged a state-of-the-art ecohydrological model and eddy covariance observations to evaluate how root and soil depth might influence plant response to drought. I applied these tools to better capture the environmental factors surrounding the recent episode of anomalous drought that have occurred in California's Sierra Nevada, from the years 2011 to 2018. The Sierra Nevada forest is an important area to properly assess, due to its proximity to urban areas that rely on the same river that flows through the forests. However, its mountainous terrain further obscures the results of atmospheric measurements due to the complex factors associated with a sloping and diverse surface, making accurate predictions of mortality based on conventional methods virtually unfeasible. As opposed to studying only atmospheric water, I will attempt to simulate both the movement of water above and below the soil. The results of this experiment will demonstrate how root and soil depth might influence plant water supply and consequently plants' vulnerability to drought.

High-Efficient Inactivation of Airborne Viruses Using A Microwave Catalytic Air Filtration System

Undergraduate researcher: Ashley Kate Suthammanont
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Mentors: Ph.D. Student Fangzhou Liu and Dr. Wen Zhang
Department of Civil and Environmental Engineering, NJIT

The COVID-19 pandemic sparked public health concerns and heavily impacted daily life in order to combat transmission of the airborne virus. 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, but do not inactivate microbial agents such as viruses. Moreover, most air filters for residential, commercial, and industrial buildings can only capture large airborne particles, e.g., dusts, mold spores, and bacteria, but not viral aerosols, which are sub-micrometers. The objective of this study was to evaluate the inactivation performance of a microwave-responsive catalyst assisted air filtration system. Compared to most current technologies, such as germicidal UV irradiation, microwave irradiation is more penetrating into materials such as aerosol droplets and filter fabrics, and induces both thermal and non-thermal effects for microbial inactivation. Instead, UV irradiation only interrupts genetic materials and may not fully inactivate or kill pathogens. Bacteriophage MS2 was used as a surrogate model virus that mimics most of the typical pathogenic viral properties such as their small sizes and surface capsid structures. Surgical masks coated with different microwave absorbing catalysts, such as BFO ($BiFeO_3$) and Mxene ($Ti_3C_2T_x$), were used on filters to evaluate the inactivation performance for aerosol MS2 virus with/without microwave irradiation. The results showed that the aerosol virus treated with only the pristine filter (no catalyst) without microwave irradiation did not have any decrease in concentration after 5 minutes of treatment due to the filter's large pore size, attributing to the release of aerosol virus. However, the treatments with the microwave and filter for 5 minutes had almost a 50% decrease in MS2 concentrations. Furthermore, the treatment with the catalysts coated filters under 5 min microwave irradiation contributed to more than 50% removal rate of aerosol virus as the radicals and high temperature hot spots may generate on catalysts and thus promote viral inactivation. In the further research, the experimental conditions (e.g., flow rate, humidity and temperatures), as well as different catalysts, will be explored to analyze the disinfection performance of our system under different environments. The resulting proposed technology can be established in commercial buildings, hospitals, transportation systems (e.g., train station/airports) and any enclosed space with high-density population to further ensure the safety of the public. Due to its quick efficiency, the microwave-assisted filtration can also be used in sudden outbreaks as an emergency air filtration response to mitigate a large rise in infectious cases.

From Conserved to Forgotten: An Analysis of the Pequannock Watershed

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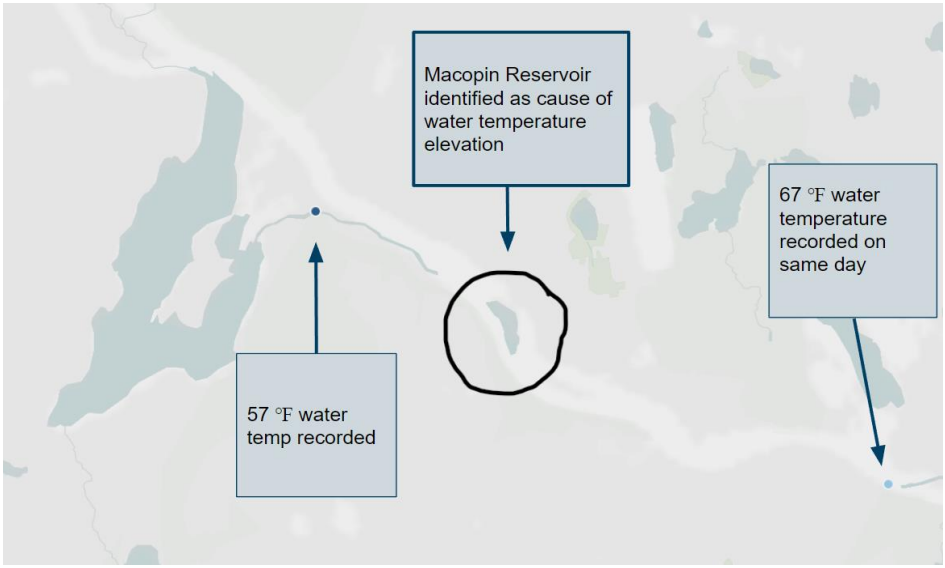
Maintaining excellent water quality in our streams is essential for everyone who relies on them for drinking water and recreational value alike. Because the decline of wild trout serves as a crucial indicator of water quality degradation, their disappearance can signify a larger issue within the streams that are the source of our water supply. Trout fishing is also a major industry in New Jersey, with over 100,000 trout stamps sold every year throughout the state. This summer I tested 16 different sights along the Pequanock river over an 8 week period from June through July, with the purpose of identifying the dominant factor limiting the survival of the wild brown trout that live there. The Pequannock river supplies water to 500,00 New Jersey residents including the city of Newark, so the trout's decline is a reason for concern. Seven parameters were tested at each stream segment: pH, temperature, dissolved oxygen, nitrates, phosphates, macroinvertebrates, and water clarity. Measurements were obtained using various electronic testing probes and kits. The results of my data analysis indicated that all factors measured throughout the river were in an acceptable range as laid forth by trout unlimited, except for water temperature. As temperatures rise, trout need more dissolved oxygen to survive, but the water can hold less of it. My data shows that the Macopin reservoir, formerly used for water supply but since decommissioned, was the most significant contributor to warming water throughout the Pequannock. Temperatures measured upstream of the reservoir were 10 degrees cooler than temperatures measured 1.5 miles downstream of the reservoir. A river segment of equal length was found to have only a 3 °F temperature elevation. Future work in this field would include working with local governments to create a plan to mitigate the negative heating effects of the Macopin Reservoir on the river's ecosystem.



The Effects of Climate Change on Public Health

Justin Vasquez, Advisor: Dr. Zeyuan Qiu
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New Jersey Institute of Technology, Newark NJ 07102

There are gaps in the state of knowledge surrounding how climate change impacts public health. Understanding climate change in relation to public health is important as the state of climate change worsens. This knowledge is necessary in order to know how to react and respond to climate change situations as they present themselves. Our research aims to help this problem by creating an integrative review of existing research that comprehensively summarizes the current state of knowledge surrounding climate change with respect to public health. This review will serve future research as reference material. I then used this review as a point of comparison for preliminary analysis I did on a dataset centered around Camden, NJ that focused on daily temperature readings and hospitalization data. What I found is that the effects of climate change in Camden are more exaggerated with more extreme heat present in comparison to previous research. The greater presence of extreme heat is likely the cause of the higher average hospitalizations for heat related illness present. With this knowledge, future work should focus on mitigating local contributions to climate change as well as preparing to address the increasing number of hospitalizations.

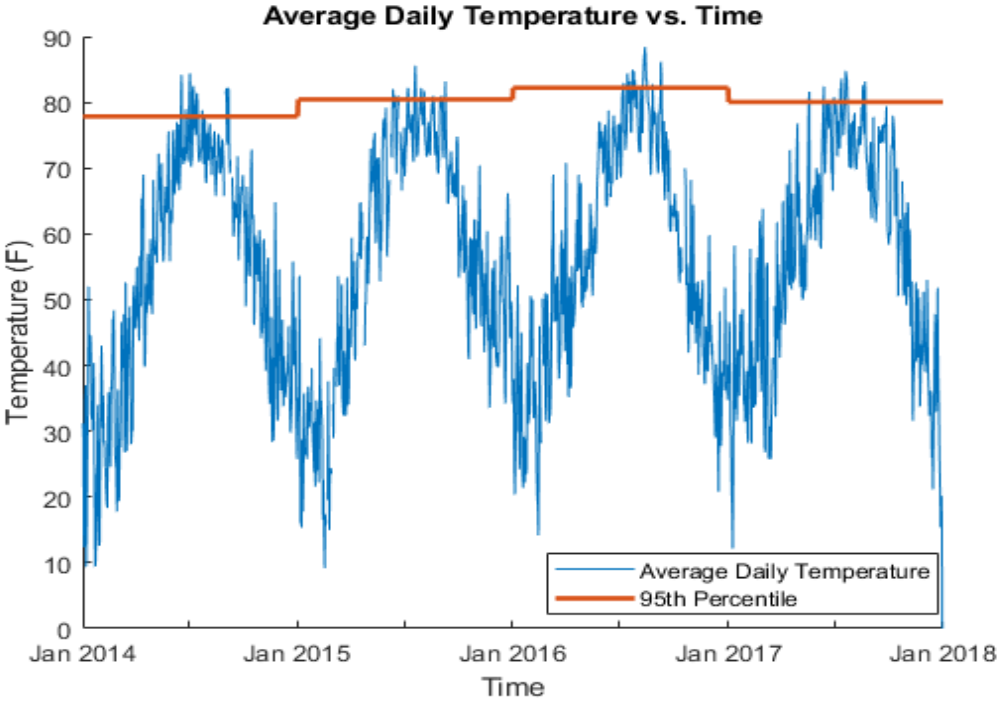

Figure 1: Plots the average daily temperature in Camden, NJ against time. Shows the 95th percentile (heat wave threshold) is increasing on average, suggesting more intense and frequent high heat exposure.

Magnetohydrodynamic Simulation of Coronal Magnetic Field Evolution and Eruption

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Mentors: Dr. Satoshi Inoue, Nian Liu
New Jersey Institute of Technology, Newark NJ 07102

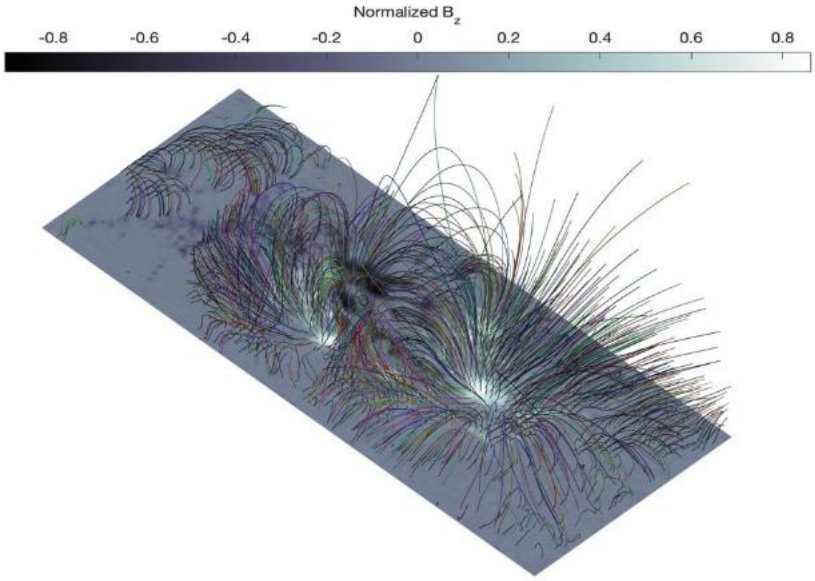

Figure 1: Magnetic field obtained from nonlinear force-free field extrapolation of photospheric magnetic field observations collected prior to the X1.3 flare observed on March 30th, 2022.

Solar flares are phenomena where magnetic energy stored in the coronal magnetic field is released through magnetic reconnection. These phenomena are the most energetic events in the solar system; illustrating their severity, the most powerful flares, designated as X-class events, release enough energy to induce global power outages in some cases. Despite extensive solar flare studies, a detailed understanding of their three-dimensional (3D) nature is elusive because the Sun's magnetic field is observed only on the solar surface (photosphere). Therefore, we need a numerical approach to know the 3D coronal magnetic field based on the photospheric magnetic field. The nonlinear force-free field (NLFFF) extrapolation method is well-known as a strong tool to reproduce 3D coronal magnetic fields. The strong advantage of this method is to reproduce the magnetic field that stores free magnetic energy (or strong current density) before the flare. In this study, we reveal a triggering mechanism of the X1.3 solar flare observed on March 30th, 2022 in terms of 3D magnetic field analysis. In order to do so, we perform and compare NLFFF extrapolations based on photospheric magnetic fields before and after the X1.3 flare. Pre-flare and post-flare photospheric magnetic fields taken by the Solar Dynamics Observatory (SDO) are used as the boundary conditions for the NLFFF extrapolation, which was performed by the magnetohydrodynamic (MHD) relaxation method (Inoue et al. 2014, Inoue 2015). The NLFFF extrapolations are run on the Solalab partition of the Lochness computing cluster. We successfully reproduced highly twisted field lines before the X1.3 flare. These highly twisted field lines accumulate strong current density and are considered as a source of solar flares. We will report the results of comparison between the pre-flare and post-flare 3D magnetic fields and twist numbers, and discuss the flare-triggering process based on these results.

Analysis of a Solar Flare in a Magnetically-Quiet Active Region

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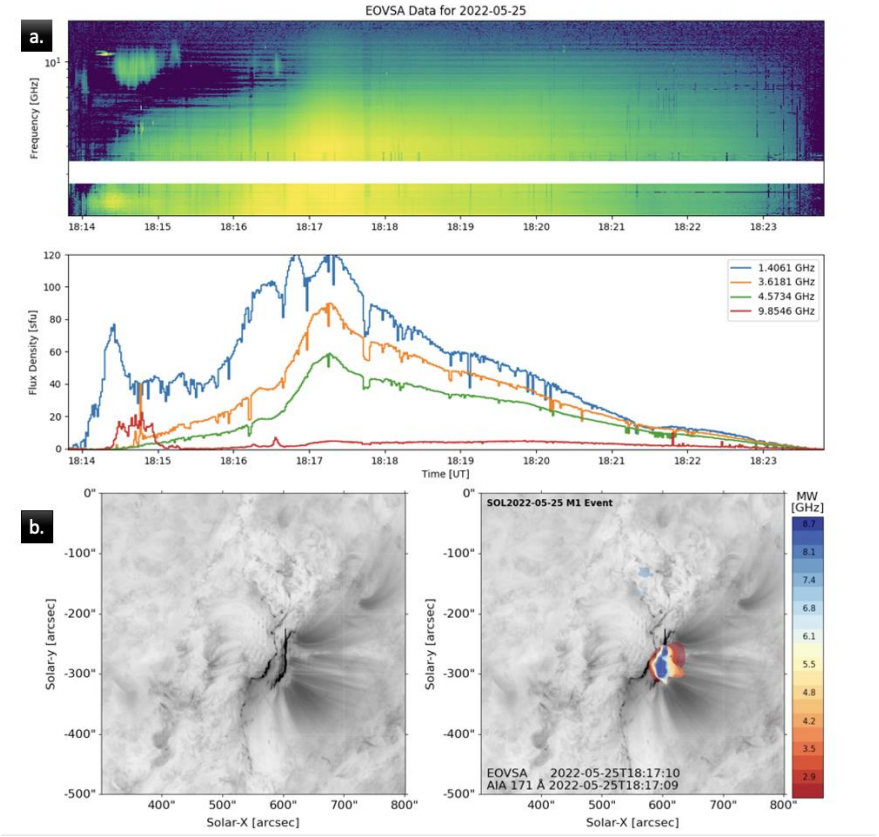
Abstract: Solar flares, one of the major drivers of space weather in the solar system, are known to be caused by magnetic reconnection in active regions (ARs) on the Sun. These flares typically occur near sunspots, which indicate regions of strong magnetic field activity where intense solar phenomena are most likely to occur. In contrast, magnetically-quiet regions are ARs without sunspots, and flares are very unusual occurrences in these regions. This study focuses on a flare with a strong signal – an M1-class flare, originating in a magnetically-quiet AR – AR13016, on May 25, 2022. For the flaring period, radio frequency observations were acquired from the ground-based Expanded Owens Valley Solar Array (EOVSA) at Owens Valley, and extreme ultraviolet (EUV) frequency observations corresponding to wavelengths 94Å, 131Å, 171Å, 193Å, 211Å, 304Å, and 335Å were acquired from the Atmospheric Imaging Assembly (AIA) instrument aboard the space-based Solar Dynamics Observatory (SDO). The flaring period was determined from the radio spectra and light curves derived from EOVSA data, shown in Figure 1(a). The data for the flare was processed in Python using several image processing tools and from the EOVSA radio data, contours were overlaid on each EUV image, which were merged to produce an animation to view changes in the magnetic structure of the AR during the flare. A frame from the flare animation in Figure 1(b) shows contours derived from EOVSA data overlaid on an AIA 171Å image.



Statistical Study of Solar Jets in Chromosphere, Transition Region, and Corona

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Abstract: Jets are an abundant phenomena in the solar atmosphere, and have been widely considered to play an important role in corona heating and solar wind acceleration. On the other hand, the data from Parker Solar Probe (PSP) discovered the existence of small transients called "switchbacks" in the solar wind. In this study, we observed the spatial and temporal distribution of solar jets during many encounter periods of PSP. Extreme ultraviolet (EUV) images from Atmospheric Imaging Assembly on Solar Dynamic Observatory (SDO/AIA), UV images from Interface Region Imaging Spectrograph (IRIS), and high-resolution H-alpha images from Goode Solar Telescope (GST) were used for the observations of jets in the corona, transition region, and chromosphere. Imaging data where GST and IRIS were both observing PSP solar wind source regions were included.

Wind Observations Using Fabry-Perot Doppler Image Data

Patricia Dzwill
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Abstract: In the latitudes around the Earth's magnetic equator, at night, a phenomenon occurs called Equatorial Spread-F (ESF) that can disrupt radio signals, GPS signals, and the like to be disrupted, which poses a problem for technology in this region. While it is known that plasma instabilities in the ionosphere are the cause of this, a predictor of this phenomenon has not been discovered. However, there is a belief that a predictor could be found by analyzing the wind speeds in this region. Situated in the mountains of Huancayo, Peru, the Second-generation, Optimized, Fabry-Perot Doppler Imager (SOFDI) instrument is a novel triple etalon full 24-hour Fabry-Perot Interferometer (FPI) capable of measuring high (~130km) altitude winds and shedding light on this question. In order to answer the question, however, a large set of sky images taken from the instrument at several wavelengths (630nm and 557nm) require post-processing analysis to be performed so that the wind speeds can be inferred. In order to better understand the source of sky image data we're utilizing in the project, we were able to assist Dr. John Meriwether, a Distinguished Research Professor with CSTR, in deployment of a 15 cm FPI at Jenny Jump State Forest with help from the United Astronomy Clubs of New Jersey (UACNJ). It was my goal for this research project to write code that could annularly integrate along the diffraction ('ring') pattern of the image and to calculate wind speeds based on the data. Utilizing the IDL programming language, I created an algorithm to identify the true center of the instrument 'ring' pattern from image data and annularly integrate this pattern. The output of this integration performed on calibration images can be seen in Figure 1. This annular integration on calibration data reflects the system pattern that will need to be accounted for in analysis of the data. Furthermore, I utilized currently existing IDL code to calculate wind speeds for a day's worth of SOFDI data. The zonal winds graphed against a current empirical wind model are pictured in Figure 2. The daytime zonal wind speeds show discrepancies from empirical models, indicating the possibility of an as-yet unknown wind pattern existing in the region. Future analysis including more wind speed measurements will help elucidate the cause of the discrepancy. Also in the future, more wind speeds will be calculated and used in further analysis to work towards a predictor for the appearance of ESF.

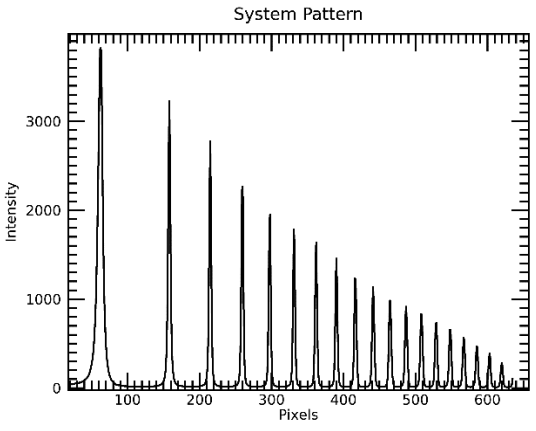

Figure 1: Annularly Integrated System Pattern

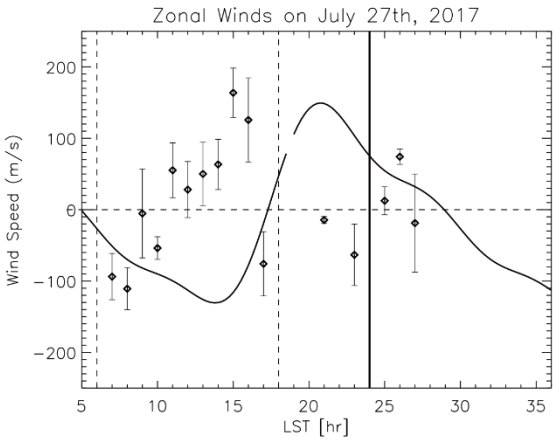

Figure 2: Zonal Wind Speeds from July 27th, 2017

Probing Energy Release in Solar Flares Using Radio and EUV Observations

Tyler Ford, Illinois Institute of Technology
Mentors: Dr. Bin Chen, Yuqian Wei
Supported by the NSF REU Site hosted by the Institute of Space Weather Sciences
New Jersey Institute of Technology, Newark NJ 07102

Abstract: Solar flares, the most dominant explosions in our solar system, are driven by explosive release of magnetic energy. These bursts of magnetic energy are facilitated by fast magnetic reconnection, a process in which magnetic field lines break and reconfigure. The release of magnetic energy accelerates a large amount of charged particles to high energies. Although the current understanding of particle acceleration mechanisms remains unclear, phenomena involved in the magnetic reconnection processes may better help us understand the context and driving mechanisms for the acceleration of energetic particles. Supra-arcade downflows (SAD) are composed of multiple dark finger shaped plasma downflows that reside in densely turbulent areas. Observational evidence suggests that these self organizing downflows are intimately related to magnetic reconnection. Although in some events, SADs have been suggested to correlate in time with radio and X-ray signatures of particle acceleration, direct observations of these emissions in the vicinity of the SADs have been elusive. This research aims to better understand the flare energy release process, by investigating supra-arcade downflows using both radio and EUV observations. In particular, we utilize radio data obtained by NJIT's Expanded Owens Valley Solar Array (EOVSA) to identify radio counterparts of SADs, especially those that indicate the presence of accelerated electrons. Primary research methods include microwave imaging spectroscopy and differential emission measurements based on multi-filterband EUV imaging data from NASA's Solar Dynamics Observatory (SDO). We analyzed a solar flare event on 2022 May 11, which shows a group of SADs in SDO's EUV images. EOVSA also captured the event. Data analysis reveals that a radio counterpart is indeed present at the location of the SADs. Upon further investigation, differential emission measures and spectral analysis show strong evidence of non-thermal electron contribution. Such contributions suggest the presence of non thermal electrons at the location of the SADs, and further strengthens the connection of SADs and the acceleration of particles.
Future research will encompass the continuation of radio and EUV data analysis, such as soft and hard x-ray comparisons, to further strengthen connections between particle acceleration and SADs.

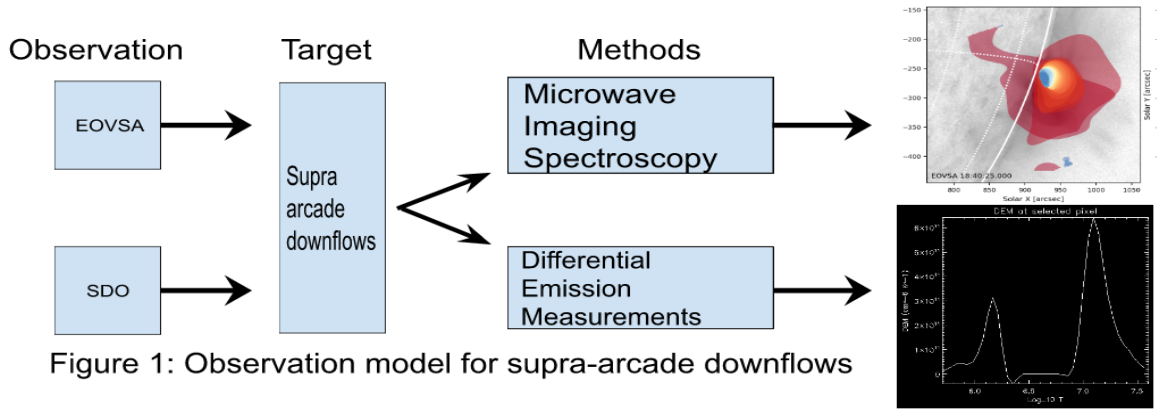

Figure 1: Observation model for supra-arcade downflows

Small Scale Solar Activity in Quiet Sun

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Institute for Space Weather Sciences
New Jersey Institute of Technology, Newark NJ 07102

Abstract: Small-scale energy release events that frequently occur in the solar chromosphere are believed to play an important role in the heating and structuring of solar corona, and acceleration of the solar wind. We analyzed high-spatial-resolution Hα images of the sun taken by the 1.6 m Goode Solar Telescope (GST) and co-aligned NASA Solar Dynamics Observatory (SDO) observations of spicules in the chromosphere and their signatures in the EUV corona. The Hα images were taken in five wavelengths ranging from -0.8A to +0.8A. We mainly looked at the blue wing (-0.8A) images because they manifest up-rising plasma in fine structures in the chromosphere. We studied corresponding 171 A images of SDO/AIA data for coronal structure.

We analyzed those data on two specific locations in the quiet sun on July 2nd, 2018. In region A, we found a poor correlation between the Hα and EUV images, and a better correlation in region B. By co-locating the HMI line-of-sight magnetogram with Hα/EUV data, we found that there are strong fields at the footpoints of chromospheric ejection features for two regions. By comparing the red and blue wing Hα images, we were able to make a residual dopplergram to see where plasma is ejecting and where it is falling back towards the sun. Our results may suggest that the activities in the chromosphere and those of the corona are more correlated in strong field regions. In the future we will look to further investigate temporal correlation of the Hα activity with its coronal counterpart for a better understanding of the relationship between the chromosphere and the corona.

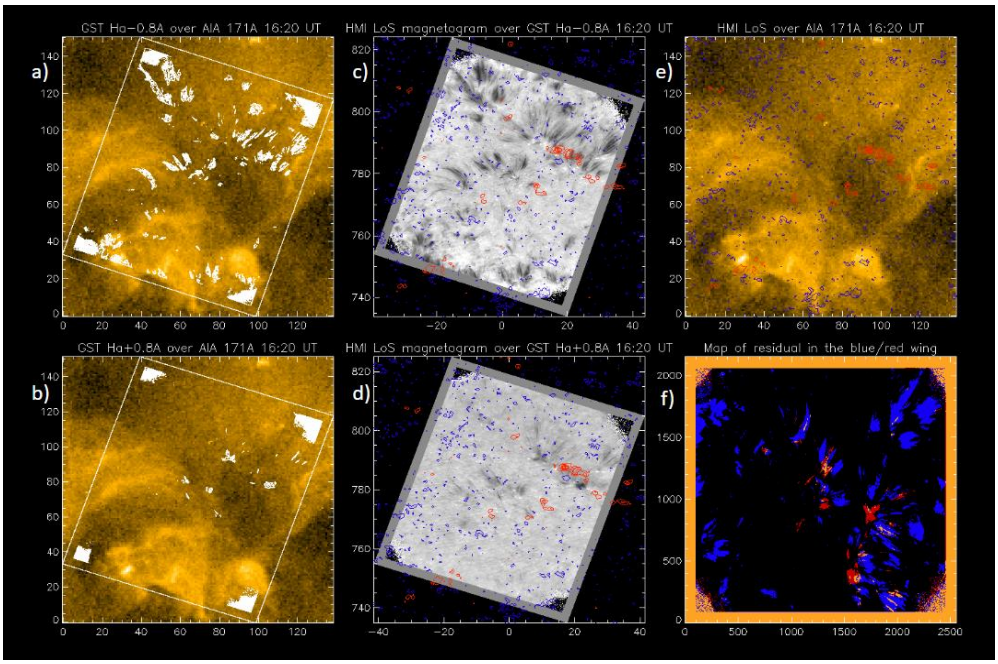

Figure 1: Hα intensity, magnetogram, and Pseudo Dopplergram. Hα blue-wing (a) and red-wing (b) intensity in white contours over SDO/AIA 171 A image. SDO/HMI LoS magnetogram (blue/red contours) over the Hα, Hα blue-wing (c) and red-wing (d) intensity images. SDO/AIA 171 A image and SDO/HMI LoS magnetogram in blue/red contours (e). Pseudo Dopplergram created by the difference between Hα blue and red-wing intensity image (f).

Avatar Creation in Education and the Metaverse

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Abstract: As of 2021, K-12 students were trailing on average 4-5 months behind their expected level of proficiency in core subjects like English and Math in the midst of the COVID-19 pandemic – and they are only falling further behind. Virtual meetings were the primary method of learning worldwide in an attempt to reduce exposure and protect the populace. As we continue to utilize virtual meeting technologies, a critique of the effectiveness of virtual education must be brought to the table. Not only did students fall behind, but their averages in courses compared to matched students from previous years were 9 to 10 points lower, creating an opportunity gap in acceptance to nationally accredited institutions. Despite the efforts of educators and students to create an effective virtual environment, long hours on a computer screen and distractions at home or in a non-classroom setting can be root causes for retention difficulties. Among video games, family intervention, and the massive appeal of internet browsing, there needs to be a push for new methods of student engagement. We propose that virtual avatars will be an effective method of increasing student engagement and prolonging the retention of educational material.

Similarly to how role models are portrayed in billboards and advertisements to convince the public to buy a product, we can use the likeness of famous figures like Captain America and Albert Einstein to teach the importance of drug avoidance or the benefits to knowing mathematics. A teacher will stand in front of a camera, and that video input will be fed into our machine learning algorithm. At the video output, the role model will appear with the pose and position of the teacher. The method by which this works is a GAN (Generative Adversarial Network), which is currently the most effective way to generate new images and video. At this time, the project has entered Phase 2, which is a period dedicated to testing existing software and upgrading dependencies. With further work, Phase 3 will be to craft our own algorithm and test the software in virtual education to acquire data on student retention and improvement.

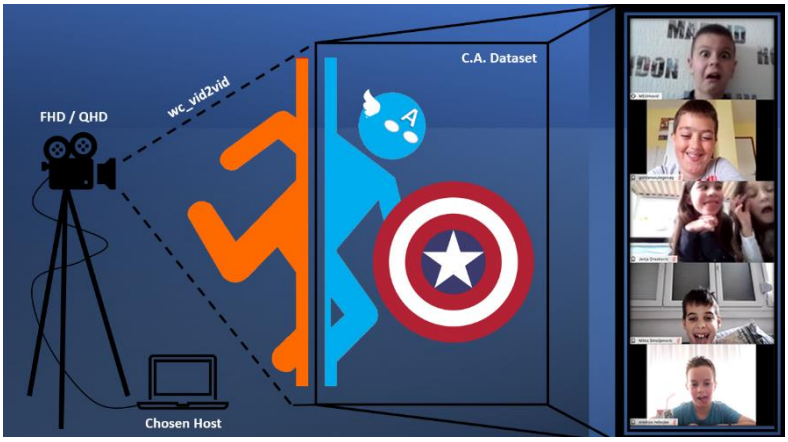

Figure 1: A visual representation of the algorithm and how it works, from camera input to the GAN (wc_vid2vid) to an output model for the students

Compounding Impacts of Climate Change and Ambient Temperatures on Mortality

Nikola Klimczak, Advisor: Dr. Zeyuan Qiu
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In 2018, the World Health Organization identified knowledge gaps regarding the consequences of warming on human health. Emerging research has shown that climate change has exacerbated non-communicable disease rates and loss of life. A deeper understanding of the current scope of knowledge is needed to determine gaps. Reports from the Intergovernmental Panel on Climate Change suggest that some observed changes in the climate are irreversible, given our current trajectory. Therefore, it is crucial to understand the implications of warming before it occurs so that policymakers and hospitals can manage its impacts. This project aimed to analyze research regarding ambient temperature and mortality; understand the current scope of knowledge and framework of these studies; and facilitate a deeper understanding of the data analysis processes to support local research. To accomplish this, I conducted a five-step systematic review. The data sources comprised Scopus and PubMed, from which I included quantitative studies from 2017 to 2022 relating to the impact of ambient temperature on various types of mortality, and excluded books, reviews, and unfinalized literature. Of the 157 articles reviewed, 40 articles remained. I found a consistent pattern of increases in mortality risks under extreme ambient temperatures, in which the severity of the increased risk differed regionally and seasonally. The systematic review suggested that non-optimal temperatures increase the risk of non-accidental, cardiovascular, and respiratory disease mortality. In the coming weeks, I will plot findings in data visualization software and assist in analyzing hospital data from Camden County in New Jersey.

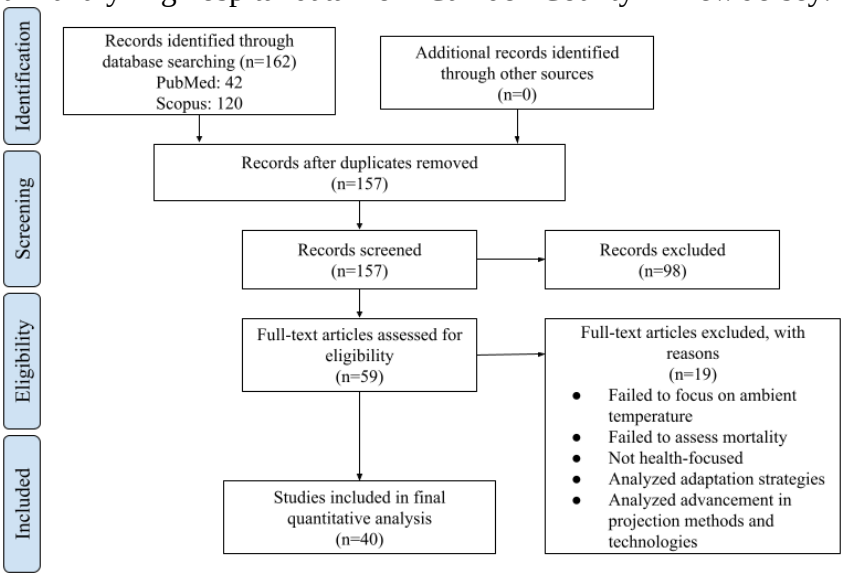

Figure 1: Preferred Reporting Items for Systematic reviews and Meta-Analyses Flow Chart

An Analysis of the Geolocation Algorithms Used by Ionospheric Radars

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Mentor: Professor Gareth Perry
Co-Mentor: Dr. Lindsay Goodwin
Institute for Space Weather Sciences REU
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The (Super Dual Auroral Radar Network) SuperDARN is a system of High Frequency (HF) (3-30 MHz) radars that detect where plasma density irregularities exist in a region of the Earth's upper-atmosphere called the ionosphere. MIT (magnetosphere-ionosphere-thermosphere) coupling process can generate large scale plasma density irregularities that can impact how radio frequency radio waves propagate through the ionosphere and are a space weather hazard. These irregularities can be detected using SuperDARN HF radars.

An ongoing and unresolved problem in using HF radar for detecting ionospheric irregularities is one of geolocation. It is difficult to accurately determine where radar echoes originate from using existing geolocation algorithms. We used PHaRLAP, a numerical ray tracing software package, to predict where the aspect angle condition is met in the F-region (between 150 and 1000 kilometers altitude) of the ionosphere. The aspect angle condition is where the radar wave vector is close to orthogonal with the local geomagnetic field. According to the current theory, HF radar echoes are generated in regions where the aspect angle condition is satisfied.

In this research project, we modeled the power flux profile on an individual SuperDARN radar located at Saskatoon, Canada, and determined where the aspect angle condition is met for that given radar. We then compared the modeled predicted to real radar echo data from the Saskatoon radar and found good agreement. One interesting result from the modeling exercise was that it predicts that echoes detected by the Saskatoon may originate from altitudes that are much lower than what is generally accepted in current literature. In the future, more analysis will be done to reinforce these results.

Solar Flare Prediction Using Machine Learning

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A solar flare is an extreme explosion that emits a burst of radiation across the electromagnetic spectrum from the Sun. While we humans on the Earth are protected from the radiation by the Earth's magnetic field, large flares can disturb the ionosphere causing disruption of signal transmission, or geomagnetic storms if coronal mass ejections (CMEs), often associated with large flares, are also released toward the Earth. Flares can be classified into different classes based on the flux of the X-ray emissions, and predicting the classes of potential flares can help us anticipate the severity of the impact they can have on the Earth. Many studies have been conducted to make better predictions using physics-based models as well as machine learning models. However, obtaining a high prediction performance has been challenging due to the uneven distribution of classes in the dataset as well as the limited number of X-class flare samples.

Our work aims to improve the flare prediction performance using different sampling methods and an ensemble classification algorithm known as stacked generalization. We utilize Synthetic Minority Oversampling Technique (SMOTE) and random undersampling to obtain a more balanced dataset to train the machine learning models. Then we build multiple different base models that would make predictions individually, and these predictions are used by logistic regression to make the final prediction of the class. We evaluate the performance of our models through a "one vs. all" approach by calculating the true skill statistic (TSS) for each class of flares. In the future, we plan to extend our machine learning techniques to predict CMEs and solar energetic particles (SEPs).

Observations of Geomagnetic Environments Using Magnetometer Data

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Space weather forecasting has become increasingly more important over the last few years. With recent events such as the loss of SpaceX satellites from a geomagnetic storm early this year, the importance of studying and predicting space weather phenomena has never been more paramount. Ultra Low Frequency (ULF) magnetohydrodynamic waves are of special notice due to the important roles they play in particle precipitation, radiation belt dynamics, ring current, as well as magnetosphere-ionosphere coupling. This puts the study of ULF waves as an important element in space weather forecasting. This project will allow us to examine how solar wind, magnetosphere, and ionosphere are coupled in the context of geomagnetic fields and current systems using magnetometer data. The deliverables will include a long-term observation of temporal and spectral variation of geomagnetic fields and their statistical trends in relation to the solar wind conditions and geospace environments. The results will be combined with the ongoing NASA and NSF projects (PI: Prof. Kim) focused on ULF wave observations in space and on the ground.

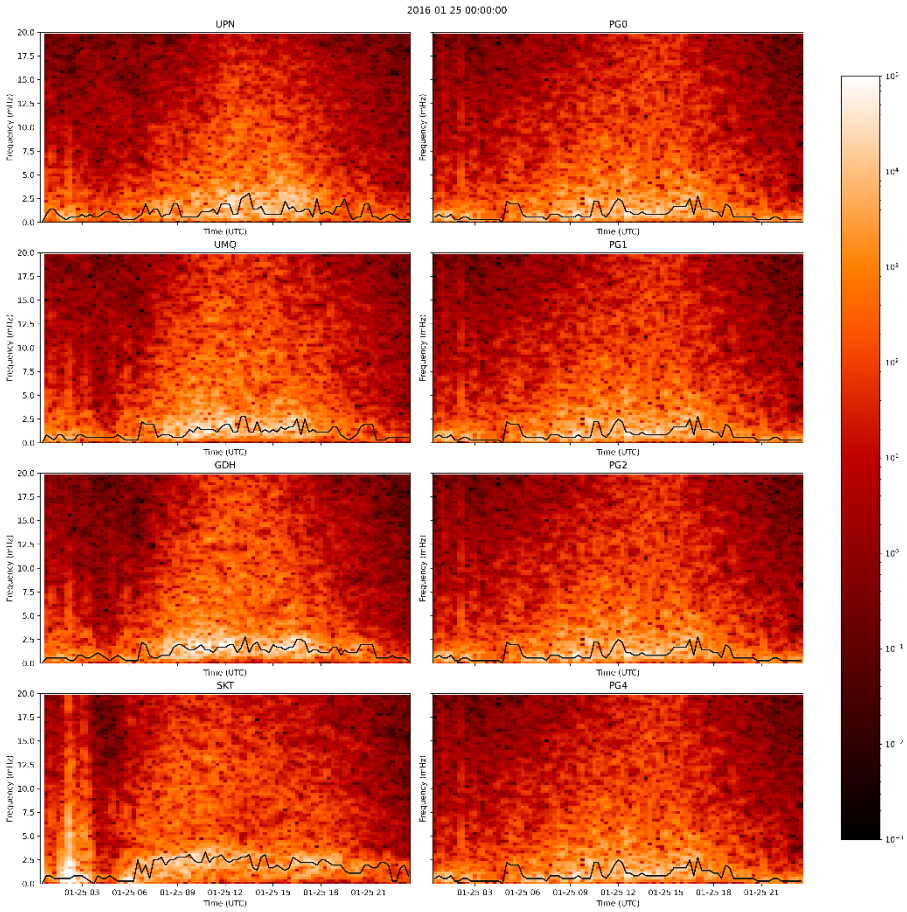

Figure 1: ULF wave observations in conjugate magnetometer stations.

Photospheric Dynamics and Coronal Heating

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Abstract: The solar corona, the Sun's furthest layer of atmosphere from its core, is the key to understanding the processes behind solar wind: the phenomenon that can create space weather storms which can disrupt the near-Earth environment. The corona's temperature is thousands of times hotter than the photosphere, its lowest layer of atmosphere, and it is known that hot plasma, or highly ionized gas, enters the corona via sporadic bursts from the solar chromosphere. Type II Spicules, fast-evolving, fine-scale plasma jet-like structures located in the chromosphere, are currently being researched as a potential link to coronal heating. These jets occur in dynamic locations of the sun, areas where magnetic field lines change connectivity often.

The goal of this project is to create a method to determine the most dynamic portions of the photosphere to track the best locations of the chromosphere to study Type II Spicules. In order to complete this task, solar diagrams that measure the strength and connectivity of the magnetic fields of the sun, called magnetograms, were used from the Near-InfraRed Imaging Spectro-polarimeter (NIRIS) operating on NJIT's Goode Solar Telescope (GST) at the Big Bear Solar Observatory. Since the most dynamic locations of the photosphere are areas of high magnetic activity, field line connectivity changes were tracked by using 27 NIRIS magnetograms. A method was created in IDL to track the magnetic field line connectivity changes by determining if each line changed its length, changed from an open line to a closed loop, or a closed loop to an open line. Plots were able to be derived from the data, showing the most dynamic portions, or where the field lines evolved the most (see Figure 1).

The code was tested for data stability through time varied magnetic flux calculations, the amount of magnetic field that passed through multiple dynamic regions as well as a control. The code requires further statistical testing but has been deemed successful in its early stages of development.

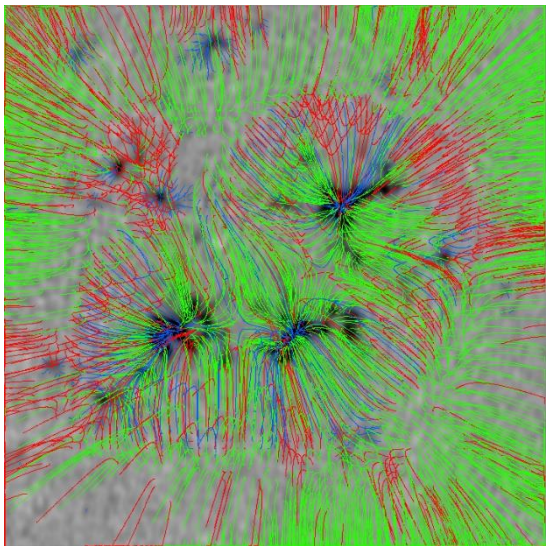

Figure 1: Plot of field line evolution using GST and NIRIS field of view magnetograms.
Color-coded lines: length change (green), open line to closed loop (blue), closed loop to open line (red).

Development of a Thermal Controller System for a GST Next Generation Instrument - VIS-II

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Abstract: Understanding the origin of space weather is crucial to meet growing technological and space-based advancements. The Big Bear Solar Observatory (BBSO) pursues this interest by observing the Sun in high-resolution with the 1.6 meter Goode Solar Telescope (GST) and its focal plane instruments. The Visible Imaging Spectrometer (VIS) is currently being upgraded to its next generation VIS-II for a wider spectrum coverage and large field view, based on dual Fabry-Perot Interferometers (FPIs). A crucial part of this upgrade will include several interference filters acting as prefilters of the FPIs, which request both a stable set temperature and programmable filter shifting. The goal of this project is to develop a thermal controlled filter wheel system to maintain 30 ± 0.1°C and have a computer-controllable rotating filter wheel. Through construction and schematic planning, the PID temperature controller box has been designed and built to maintain the temperature requirements within the filter wheel box. The filter wheel box has been assembled and tested with Arduino code adapted for filter selection. The whole system has been integrated into the VIS-I to perform imaging spectroscopy of Fe I 617.3 nm in GST Coude Lab. The results show consistency of temperature and friendly interface for filter-wheel control, which meet the VIS-II system design requirements. This system will be integrated into VIS-II once its construction is complete this Fall, which is expected to bring unprecedented high-resolution spectroscopy of the solar atmosphere and therefore significantly advance the understanding of our star.

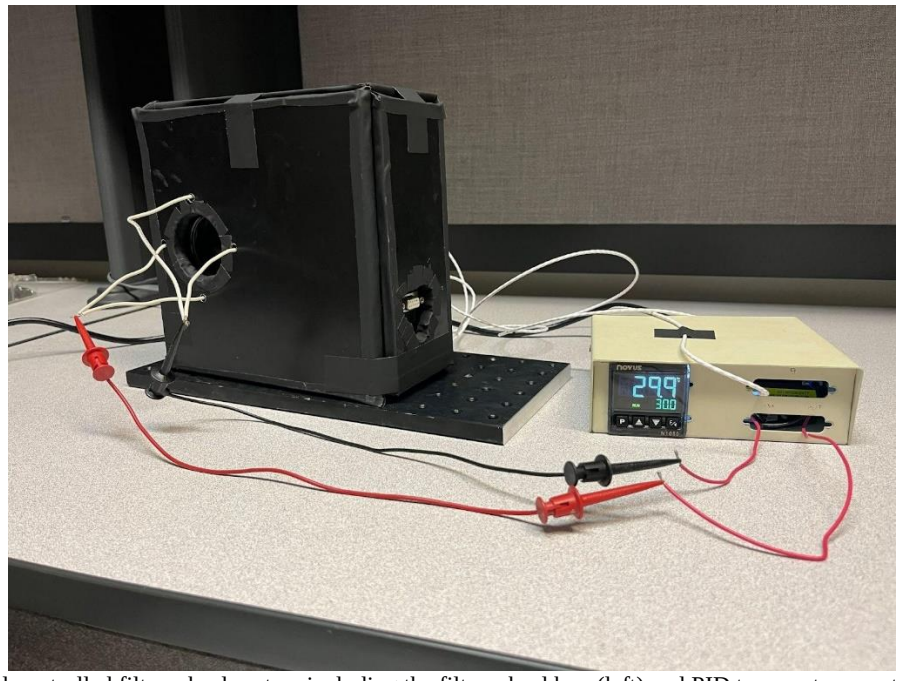

Figure 1: Thermal controlled filter wheel system including the filter wheel box (left) and PID temperature controller box (right)

Mechanism Animation and Creation of Innovative Mechanisms

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While we may not notice, mechanisms are found all around us. From being in a household item, such as a lamp, to being a part of an intricate machine, mechanisms can be exploited in a number of applications. However, because many mechanisms have been illustrated as 2D models in textbooks, understanding them efficiently can be difficult. In order for engineers to grasp the concept, they need to see them in action. This research is aimed to use 3-D animations to demonstrate the intended motions of the mechanisms. An example of the application of the 3D animations to a real world scenario is the creation of the electric flosser. According to the Centers for Disease Control and Prevention (CDC), more than 75% of Americans suffer from gum disease. Not only can gum disease cause irreversible damage to one's bone structure, but it can also be linked to heart disease or having a stroke. One of the causes of gum disease is the buildup of plaque, which if not removed can hardern and form tartar. While brushing can remove some of the bacteria, plaque can be eliminated through flossing. Despite this, only about 30% of adults floss daily. To combat this problem and to encourage flossing from a younger age, I decided to create an electric flosser. The first part of my designing process included 3D modeling through Creo Parametric. With the designing of each part (the shaft, the gears, the crank, the casing) a mechanism was created for the model. The mechanism allowed for us to develop a video where the assembly can complete the desired movement. The mechanism of the electric toothbrush allowed us to observe how the gears would work together and what the motion of the flosser would be. Along with 3D modeling and creating mechanisms, 3D printing was also implemented, making it possible for us to have tangible components, which can then be assembled to produce a working electric flosser. Similar to the motions of an electric toothbrush, an electric flosser provides back and forth oscillating movements in order to swiftly glide in between the teeth to remove plaque buildup. As the world is largely influenced by technology, having the chore of flossing also automationized will hopefully encourage more to floss.

A Multiscale Physiologically-Based Pharmacokinetic Model to Simulate Dermal Exposure to Chemical Warfare Agents

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Abstract: Given the current state of affairs in the world, military personnel and civilians risk lethal exposure to toxins. Chemical warfare agents (CWA) can permeate through the outer skin layer and profoundly affect the victim. They can also be absorbed through chemically protected clothing and enter the blood capillaries, causing systemic poisoning. These topics are usually not covered in standard undergraduate curricula, deeming research in the field to have inherent value. The main objectives of the work to be presented include 1) conducting an exhaustive literature review to identify a list of CWA and their physicochemical properties, 2) identifying the mathematical models used to capture the transport phenomena and 3) simulating the effects of pertinent factors on the fate of the CWA present in the gas phase. Step one is to be achieved by developing a basic understanding of not only transdermal uptake but the human anatomy and the function of various "compartments". Step two is to understand the mathematical equations and operations which are involved in the process. The third and final step relies upon coding in Wolfram Mathematica, a programming language which contains libraries to handle matrix manipulations, partial differentiations, and derivative calculations. The effects of physicochemical properties on the dermal absorption and evaporation are investigated.

Molecular Dynamics Study of Different Mechanical Properties of Materials

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Mentor: Joy Datta, PhD student
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Abstract: The special mechanical properties of nanomaterials allow them to have enormous applications spanning across various industries – healthcare, batteries, nanomedicine, electronic devices, biosensor, solar panel, micro-robotics, etc. Various nanomaterials are used in real-life applications such as 2D materials, carbon nanotubes, nanoscale silicon, copper, etc. In any application, understanding the following mechanical properties is of utmost importance: elastic modulus, shear, friction, fracture. In most cases, it is crucial to know these mechanical properties before using nanomaterials in manufacturing for real-life applications yet determining these mechanical properties by experiments has proven to be very expensive, time consuming, and involve many other difficulties. The trial-and-error method requires too many resources and unable to be considered a viable solution. On the other hand, Molecular Dynamics (MD) can solve these critical issues by providing a manner to determine properties and predict results using a computer that can serve as guidelines for experimentalists to further their research. Therefore, with the use of the Large-Scale Atomic/Molecular Massively Parallel Simulator we performed molecular dynamics simulations in order to characterize the behavior of materials in the effort to provide information for real world applications and further real-life research.

Permanent Magnet Integrated Shock Absorber and Electric Generator

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Contact dependent systems such as gears and springs have historically defined the process of mechanism development. Albeit effective, these contact-reliant components have hosts of defects including, but not limited to: a need for expensive materials to resist wear and tear, constant maintenance or replacement, the cyclical application of lubricant, and a relatively large carbon footprint. The magnetic augmentation of said systems can resolve these issues by introducing a near-contactless method of operation. More specifically, the design in focus is fundamentally a piston-styled shock absorber capable of generating energy as a product of applied force.

The system absorbs shock in two separate manners. The first is due to repelling magnets oriented on two separate plates that oscillate in closeness depending on applied force. The second is via the internal section of the piston, where an incompressible fluid is forced to flow through small holes in a magnetically fitted oscillating plate. By placing copper coils surrounding the magnet's direction of translation in both methods of shock absorption, currents can be generated- thus introducing passive energy generation as a product of shock absorption.

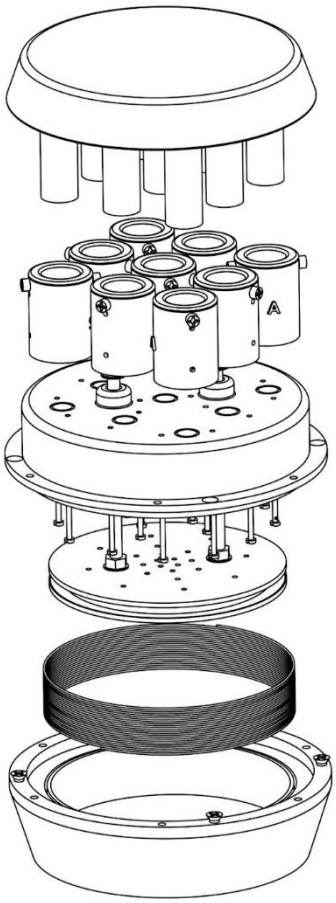

Figure 1

Due to the nature of permanent magnets and their relationship with alternating current production, the design and experimental analysis of the mechanism at hand is designed to function under several constraints. Primarily, an incident rotation caused by conflicting magnetic fields occurs perpendicular to the desired direction of translation. In addition, magnetic repulsion rapidly scales as distance reduces, limiting the effectiveness of instantaneous shock absorption. Finally, all coils must be routed to an external powersource regardless of the system's dynamics.

The 'Permanent Magnet Integrated Shock Absorber and Electric Generator' (Figure 1). Halts unwanted rotation via steel poles routed through translational bearings. Furthermore, all coils are routed through a circuit containing a full bridge rectifier- allowing all produced current to be stored. Finally, a recursive variation of the design has been modeled with the intention of amplifying all results obtained. Current assessments utilizing 24 and 28 gauge coil project current output values are to be determined and analyzed between the writing of this abstract and the URI Symposium (Jul. 27-28). All data in reference to the non-recursive model concerns the application of 10x10 cylindrical neodymium magnets in a physical testing environment. Data concerning the recursive variation is based on estimates made from the singular variation.

PbSe Mid-Infrared Colloidal Nanocrystalline Photodetector

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Abstract: Every hot object releases infrared radiation in a variety of wavelengths, which can be measured using photodetectors. Within the infrared spectrum, mid-wavelength infrared (MWIR), or the 3μm to 5μm range, is particularly useful in military applications, industrial monitoring, and proximity detection. The ever increasing demand for MWIR detectors has revealed some key flaws in the existing technology, however. Existing MWIR detectors are incredibly exacting to fabricate, which drastically increases cost, and require cryogenic operating conditions to achieve the best performance. This has created the desire for room temperature, inexpensive MWIR detectors. PbSe as a photodetector is a 70+ year old technology that has recently undergone a resurgence due to its ease of fabrication and room temperature operability. This project focuses on a new method of obtaining MWIR response from PbSe that results in a high responsivity. While traditionally PbSe devices fabricated using chemical bath deposition (CBD) have been used in detectors, this research proposes to instead fabricate devices from a PbSe nanocrystalline solution. This nanocrystalline technology offers several important qualities such as solution processability, which improves fabrication throughput, a quality in which traditionally fabricated polycrystalline PbSe is lacking. Traditionally, PbSe has required a sensitization process to exhibit MWIR response. The mechanism behind this is not yet fully understood, however it is known that both oxidation and iodization play critical roles. In traditional CBD PbSe, this sensitization is accomplished with high temperature oxidation and treatment in an iodine vapor chamber. In this colloidal nanocrystal solution research, oxidation is performed by annealing the devices in air at 350°C, and iodine is introduced by treating the devices with potassium iodide after each deposited layer of particles. The result of this project was the successful fabrication of room temperature viable, easy to manufacture PbSe MWIR devices with a high responsivity of 1.1 A/W at a 4μm peak.

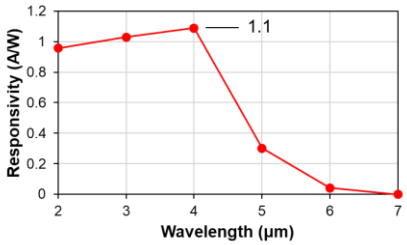

Figure 1: Spectral responsivity of the sensitized PbSe photodetector at 300K and 2V bias.

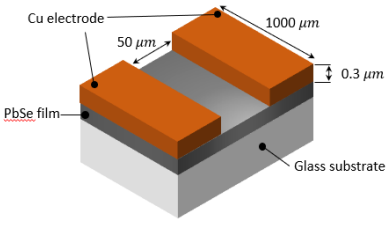

Figure 2: Fabricated PbSe device schematic

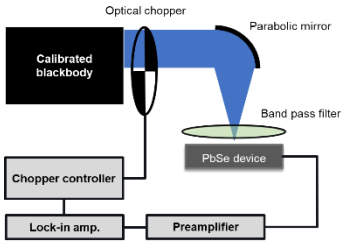

Figure 3: Responsivity characterization schematic

Novel Vertical Chemical Vapor Transport of Quantum Materials

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Abstract: Thick, high-quality, single crystals of quantum materials (QM) are difficult to synthesize using the conventional method of horizontal chemical vapor transport (CVT). The methods of studying crystal structure and magnetic properties of QM include X-Ray Diffraction, Neutron Diffraction, and Vibrating Sample Magnetometer, and they each need a high–quality sample in order to provide useful data. If QM can be studied further, new applications in nanotechnology are sure to arise, as quantum materials already have great potential, as has been shown in previous papers. To ensure further progress in nanotechnology through creating high-quality QM crystals, we propose a novel crystallization method, vertical CVT. The gravity will be employed as an external parameter to optimize the crystal growth and crystal quality. It will be attempted with the chiral helimagnet Cr1/3TaS2. Our results could also benefit the growth of various other quantum materials, and prompt the further study of the novel physics in quantum materials.

Fabrication of Reduced Graphene Oxide Quantum Dots

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Graphene Oxide quantum dots are effectively dimensionless semiconductor particles with a diameter between 1 and 10 nm. Quantum dots have applications in many technology sectors, however the lack of negative metabolic effects that graphene has makes these particles promising candidates for drug development research. As research on these particles is still in its infantry, there is a literature gap regarding the effects of oxidation and reduction on the characteristics of quantum dots. Using high power probe sonication, reduced graphene oxide was successfully exfoliated down to a diameter of approximately 6 nm. This was confirmed using DLS technology. Using this technique, quantum dots made from various elemental compositions will be fabricated and subjected to characterization tests to observe how the level of reduction effects their applications in drug development and delivery.

Experimental Investigation of Flow Within Dissolution Vessels using Particle Image Velocimetry

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Abstract: In-vitro drug dissolution testing is used as a tool determine the rate of dissolution of solid dosage forms, such as tablets. The results of the test can provide valuable information about the corresponding in-vivo (in body) drug dissolution process. The dissolution rate in the system can be used to assess bioavailability, therapeutic effectiveness, quality control, and performance of drugs in the pharmaceutical industry. Many non-compendial (not listed in the US Pharmacopeia) dissolution systems are currently used in industry, such as mini vessels or small-volume vessels. However, the hydrodynamics within these systems has not been investigated. Therefore, the purpose of this project was to determine the velocity profiles inside different mini vessels. This project involved conducting an experimental investigation aimed at characterizing the velocity profiles in multiple small-scale dissolution testing vessels and to do so under different operating conditions. Particle Image Velocimetry (PIV) is the optical method that was implemented to determine instantaneous fluid flow and velocity fields within the mini vessel systems we investigated. The information gathered from the mini vessels provided by Merck (Pharmaceutical Company), if given to industrial researchers, will be utilized to understand the hydrodynamics within plant scale industrial equipment. In addition, the results of the Chinese Pharmacopeia vessel experiments will provide a new standard to the dissolution process.

Effect of Molecular Weight on the Curing of PEGDA Hydrogels

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Abstract: Digital light processing (DLP) 3D printing technology has been advancing and is widely used to make medical devices, implants, chips, tissues, and drug delivery systems. The main hydrogels that are used in this additive manufacturing technology are gelatin methacryloyl (GelMA) and polyethylene glycol diacrylate (PEGDA) because of their photopolymerization effect and good biocompatibility with cells. In this project, we analyze the impact of molecular weight, in PEGDA solutions, on curing properties under a DLP printer. Solutions containing 20% PEGDA and 0.5% Lithium phenyl-2,4,6-trimethyl-benzoyl phosphinate (LAP) were made for the varying molecular weights of 575, 700, 4000, and 6000 Mn. As the molecular weight increases, the curing time also increases, however, the resolution decreases. Higher molecular weights cause the density per volume of the acrylate in the ink to decrease which reduces the resolution of the product. In the future, this data could be used to determine the appropriate PEGDA molecular weight for different applications; In tissue engineering, the most appropriate PEGDA to use would be 575 Mn because it will provide high-resolution prints.

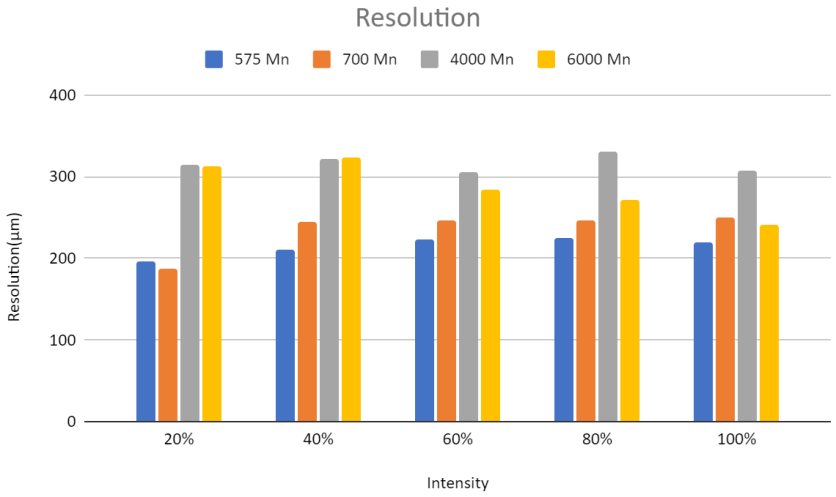

Figure 1: Resolution of 20% PEGDA and 0.5% LAP solution of varying molecular weights at different light intensities

The Effect of Surfactant on the Glass Transition Temperature of PLGA Nanoparticles

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Currently, manipulating the drug release behavior of PLGA nanoparticles is difficult to do without changing the structure of the particle. Additionally, PLGA tends to release drugs in a short burst. Developing ways to alter delivery times for cancer drugs depending on the need is important for cancer treatment. This project aims to investigate the drug release behavior of PLGA nanoparticles made using DMAB and PVA, two completely different surfactants in structure. PVA is a large polymer chain whereas DMAB is a small ionized non-polymer. Depending on the surfactant, the glass transition temperature (Tg) of PLGA nanoparticles will go up or down. Additionally, the drug release behavior of a polymer's nanoparticles is shown to be linked to its Tg; therefore, by measuring the Tg, the drug release behavior of the nanoparticles can be inferred (Takeuchi et al. 2017). Furthermore, measuring the particle size is essential in determining if the nanoparticles would be useful in drug delivery. For example, a range of 100nm-200nm is generally preferred for PLGA nanoparticles.

During the summer, PLGA nanoparticles were made using 5 separate concentrations of both DMAB and PVA. Using DSC, the Tg of each sample was measured in both dry and wet conditions. In the results obtained for wet conditions, DMAB consistently has a higher Tg than PVA (Figure 1). In dry conditions, DMAB has a higher Tg at lower concentrations but equalizes with PVA at higher concentrations (Figure 2). Based on the results, it can be concluded that simply by changing the surfactant used, the Tg and thus the drug delivery behavior can be altered to improve cancer treatments.

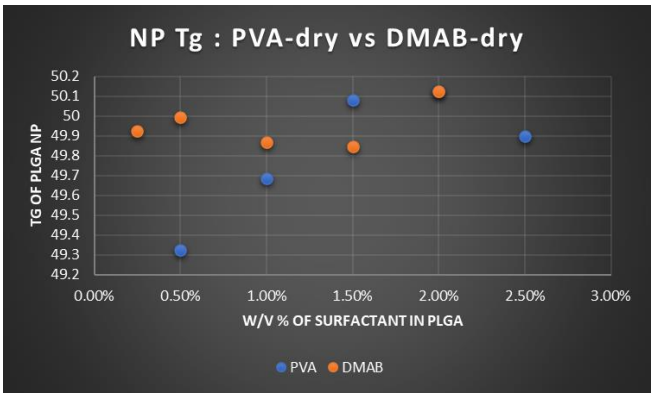

Figure 1. PVA-dry vs DMAB-dry

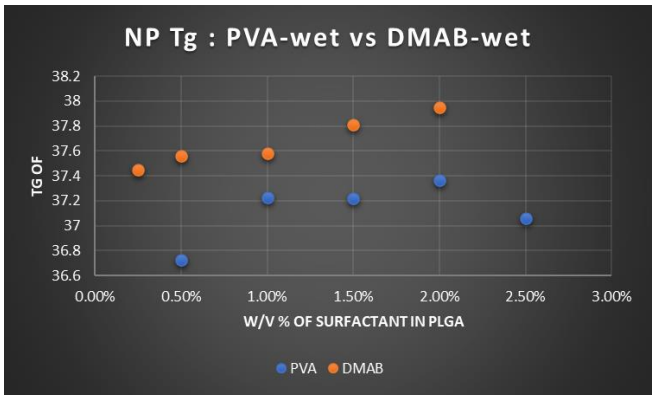

Figure 2. PVA-wet vs DMAB-wet

Enhancing Efficiency of AlGaN UV LEDs by Optimizing Electron Blocking Layer Structure

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UV LEDs have many applications in society today. They are used to sterilize COVID and other bacterias, treat dermatological disorders like jaundice and psoriasis, and are even being used in horticulture as a farming alternative decreasing land and water resources previously needed to grow crops/ plants. Even though UV LEDs are commonly used, they have very low efficiency. Low efficiency in LEDs leads to them using more energy and having more heat waste that is released into the environment. This project will be focusing on enhancing the efficiency of AlGaN UV LEDs by optimizing an electron blocking layer (EBL) structure. SimuApsys software was used to simulate the different EBL variations. To measure EBL optimization, each simulation tested for LED Power v Current data, LED Efficiency v Current (IQE) data, and Radiative Recombination data. First, changes to the AlN percent concentration in AlGaN in the EBL was simulated from a range of 50 to 80% finding 50% to be most optimal. Using the 50% AlN percent concentration in AlGaN in the EBL, more simulations were run with changes to the EBL thickness ranging from 0.01 to 0.06 μm. The optimal EBL parameters from the ranges used were identified as 50% AlN percent concentration in AlGaN in combination with a 0.01 μm EBL thickness. The next step for this project will be to continue working towards efficiency and optimization by changing parameters of quantum wells in AlGaN UV LEDs.

Effect of Water Vapor Adsorption on Wave Propagation in Nanoporous Media

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Fluid adsorption alters many physical properties of porous materials, including the elastic prop erties. Ultrasound characterization studies and geophysics theories are affected by the presence of fluid adsorbed in porous media. This phenomenon has been explored in macroporous sandstone, showing that water adsorption decreases the ultrasound speed, implying a decrease in elastic mod ulus. The effect of water adsorption in nanoporous media is under-explored, but is important to technologies in which nano-confined water is a major component, such as purification systems. This area of study is also pertinent to understanding other nano-confined fluids such as shale gas. In this work, ultrasonic wave propagation is used to study the effects of water adsorption on the elastic modulus of nanoporous Vycor glass. A robust ultrasound-adsorption system is constructed to measure the time-of-flight of sound waves in the sample at multiple stages of adsorption. The ultrasound speed is found to increase with water adsorption, implying an opposite effect to that found in sandstone. The system will be applied to studies of other fluids in porous media.

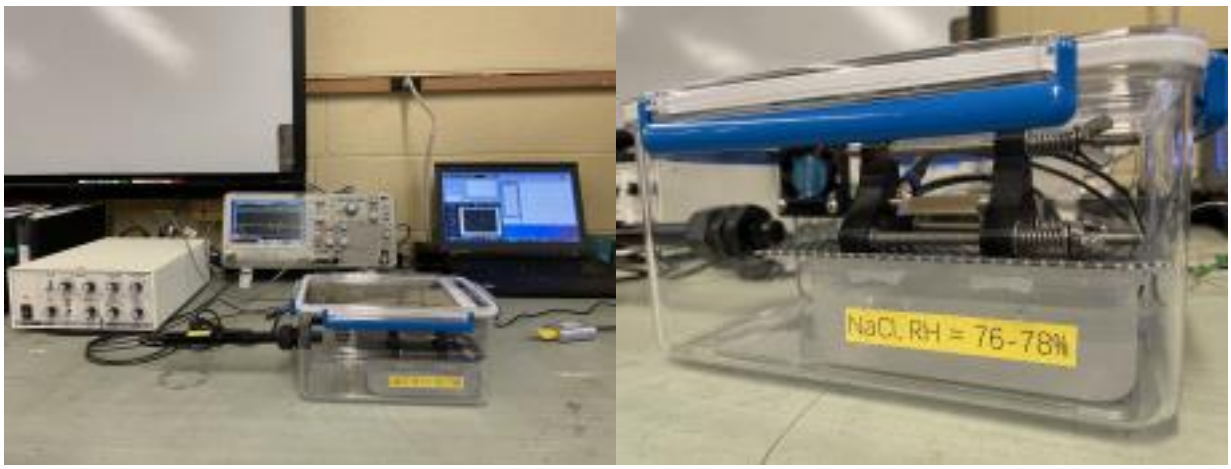

Figure 1: Left: Full ultrasound-adsorption system (left to right: pulser/receiver, digitial oscilloscope, adsorption chamber, monitor). Right: Close-up of adsorption chamber and Vycor sample.

Experimental Determination of Hydrodynamics Within Dissolution Minivessels Using Particle Image Velocimetry (PIV)

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Abstract: In-vitro (in glass vessel) drug dissolution testing is mainly used as a tool to assess drug performance in the pharmaceutical industry. It can provide critical information about the corresponding in-vivo (in body) drug dissolution process. Certain non-compendial dissolution systems are commonly used in industry, such as minivessels or small-volume vessels, although the hydrodynamics, or fluid motion within the system, is relatively unknown. The determination of velocity profiles in minivessels will contribute to understanding the mixing process in this system. As a result, we can determine how a drug disperses through the vessel as the dissolution process continues. Therefore, the goal of this project is to conduct a detailed experimental investigation aimed at fully characterizing the velocity profiles in the Chinese small volume vessel and to do so under a multitude of operating conditions. Particle Image Velocimetry (PIV) will be used to determine the fluid flow within the system which will later be translated into velocity contour maps.

Different pieces of equipment were designed for the purpose of accurately and precisely calibrating the system. This equipment included a lateral traversing system, a stage used to tip and tilt the minivessel, and a centering device to ensure that the rotating shaft was directly in the middle of the vessel. The minivessel was then charged with water and fluorescent red polyethylene particles. These PIV seeding particles were to be used as tracer particles because they are large enough to scatter the light from the laser sheet, making them visible to the PIV camera, but small enough to follow the fluid motion without affecting the flow. Once experiments were concluded and the PIV calculated the velocity profiles within the minivessel, contour maps were produced to observe the flow of liquid more easily. Results were compared to that of known drug dissolution profiles in other similar full-sized systems which proved the accuracy of our methods. In the future, research involving non-compendial minivessels will be conducted and a paper will be published to a high impact pharmaceutical journal.

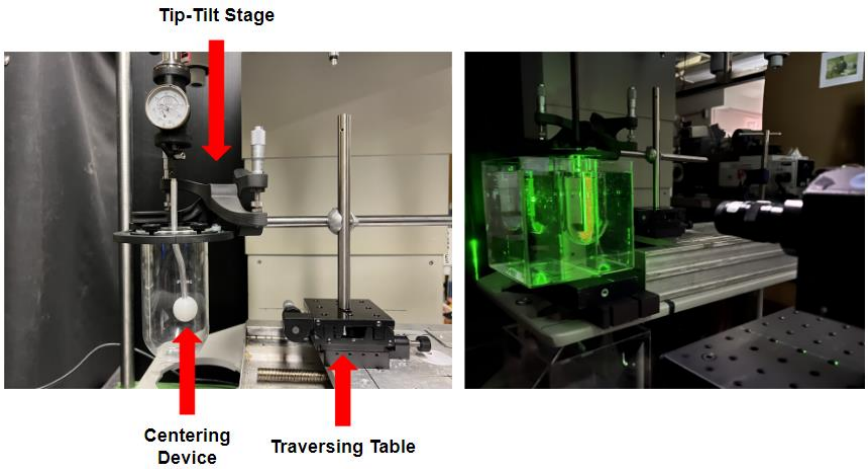

Figure: Equipment designed for calibration (left) and PIV laser sheet used to illuminate fluorescent nanoparticles (right)

Removal of Impurities from Nitrogen-Doped Graphene (N-G) Electrocatalyst for Electrochemical Energy Conversion and Storage Systems

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Abstract: Catalysts are an integral part of modern electrochemical energy conversion and storage systems (e.g., fuel cells, batteries, etc.), ensuring that chemical reactions at the positive and negative terminals of such systems occur at an efficient rate. The purpose of graphene-based catalyst research is to decrease the cost of production for modern electrochemical energy systems without compromising catalytic performance (as compared to current platinum-based catalysts). An electrocatalyst was developed from nitrogen-doped graphene (N-G) through a Nanoscale High Energy Wet (NHEW) Ball Milling process. The N-G catalyst demonstrated electrochemical performance comparable to the standard 10% Platinum supported on Carbon (Pt/C) catalyst. However, the NHEW Ball Milling synthesis process led to some anticipated impurities in the catalyst, specifically zirconia (introduced from the high-density magnesia-stabilized zirconia balls grinding media). This study investigates multiple methods to reduce such contaminations of the N-G catalyst sample while keeping the catalytic performance unchanged. The zirconia impurities, though electrochemically inert, are necessary to remove as it adds significant weight to the sample which reduces the loading efficiency of the catalyst. By reducing the amount of zirconia in the sample, necessary catalyst loading could be lowered to obtain the same catalytic performance, allowing the catalyst to be more efficiently implemented. Furthermore, by achieving a purer N-G sample in terms of zirconia contamination, the true catalytic performance of the sample will be characterized more precisely, allowing for more accurate comparisons to other catalyst alternatives. In this study, first, the reduction of zirconia impurities from the N-G catalyst was attempted by using an alternative grinding media, Yttria-stabilized Zirconia (YSZ), because of the better compressive strength and density of the material than the previous grinding media. Concurrently, a post-synthesis removal of zirconia was performed through a centrifugation process on samples synthesized with the previous grinding media. The centrifugation method takes advantage of the high density of the zirconia relative to the N-G catalyst, allowing for the upper catalyst layer to be removed after the centrifugation process. Electrochemical performances of N-G catalyst samples were evaluated before and after the impurity removal process by a rotating disk electrode (RDE) system in terms of current density generated from the catalyst samples by the oxygen reduction reaction (ORR) in the alkaline medium (0.1 M KOH). Through this impurity removal process, the catalytic performance of the N-G catalyst was improved by about 6.1% in terms of obtained ORR current densities for the same catalyst loading.

Perfluorooctanoic Acid (PFOA) Detection Using Electrochemical Impedance Spectroscopy (EIS) and Metal-Organic Framework Enhanced Microelectrodes

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Perfluorooctanoic acid (PFOA), also called the "forever chemical" due to its persistency in the environment, is a highly toxic industry effluent commonly found in tap water. Perfluorooctanoic acid (PFOA) is carcinogenic even at low concentrations, thus the typical concentration of PFOA approved by the EPA is around 70 ppt/L. Typically, these molecules are detected using advanced methods like high-performance liquid chromatography, in which water samples must be transported to labs with suitable equipment. ESSENCE electrochemical sensors, on the other hand, have a notable sensitivity and selectivity similar to these methods. In addition, ESSENCE is portable, giving it field-based capabilities.

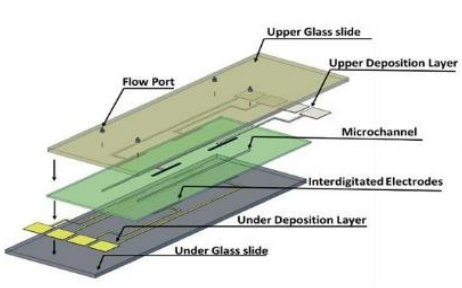
These sensors consist of two glass slides with gold microelectrodes attached and flow ports. The tape channels are placed between these slides where the desired solution flows through, and the desired capturing material is attached to the electrode **(Figure 1)**. A solution pumps through the device, and at certain intervals, the device is momentarily attached to an impedance analyzer and undergoes electrochemical impedance spectroscopy (EIS) **(Figure 2)**.

Therefore, our goal was to implement this detection technology in ESSENCE by enhancing the gold electrodes with various metal-organic framework (MOF) types. Metal-organic frameworks are well-suited for capturing Per- and Polyfluoroalkyl Substances (PFAS) like PFOA because their porous structures can hold large PFAS molecules.

Previously, Chromium and Iron-based MOFs were implemented in these devices. However, Zirconium-based MOFs, like UiO-66, have also shown excellent sorption capabilities with perfluorooctane sulfonate (PFOS) and PFOA. Hence, our goal was to test UiO-66 as a sorbent in ESSENCE over several PFOA concentrations.

Once a significant number of concentrations of PFOA concentrations were tested, we could create a calibration curve and use this information to detect the concentration of PFOA in tap water. Another MOF type, known as UiO-66 NH_2, can also be used to capture these molecules.

Figure 1: Schematic of the ESSENCE sensor and its components.



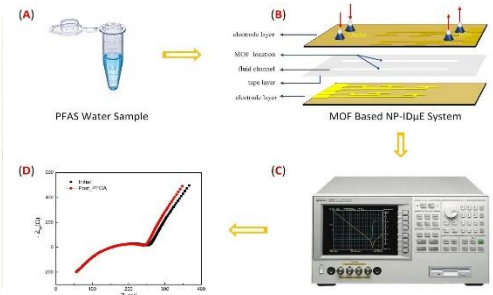


Figure 2: Schematic of the entire experimental process for PFOA detection.

BODIPY-Based Photobase Generator for Visible-Light-Initiated Thiol-Michael Addition Polymerization

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Abstract: Photopolymerization is a highly efficient and green process in the field of material science with a wide range of applications in coatings, inks, adhesives, and biomedical devices. Functional systems that can be mediated by an external stimulus such as light are crucial as they can aid in polymerization and control the procedure with high spatiotemporal resolution. The thiol–Michael addition is a powerful "click" reaction utilized broadly in polymer chemistry, but the report of photo-triggered thio-Michael polymerization is rare. Herein, we designed, synthesized, and evaluated a BODIPY-based highly reactive and effective catalyst protecting a strong base tetramethyl guanidine (TMG) for thiol-Michael addition reactions. The visible-light sensitive photobase generators are prepared in four steps starting from 2,4–Dimethyl pyrrole and Acetoxyacetyl chloride and resulting in a BODIPY-based photo-protective group (PPG) protecting TMG. The structure and the properties of the final compound are studied by ^{1}H NMR, ^{13}C NMR, high-resolution mass spectrometry, and UV−visible spectroscopy. This "photo-click" reaction enables controlled polymer network formation in thiol-Michael polymerizations which can be further utilized for surface patterning, 3D printing, film development and biological application like pH balancing.

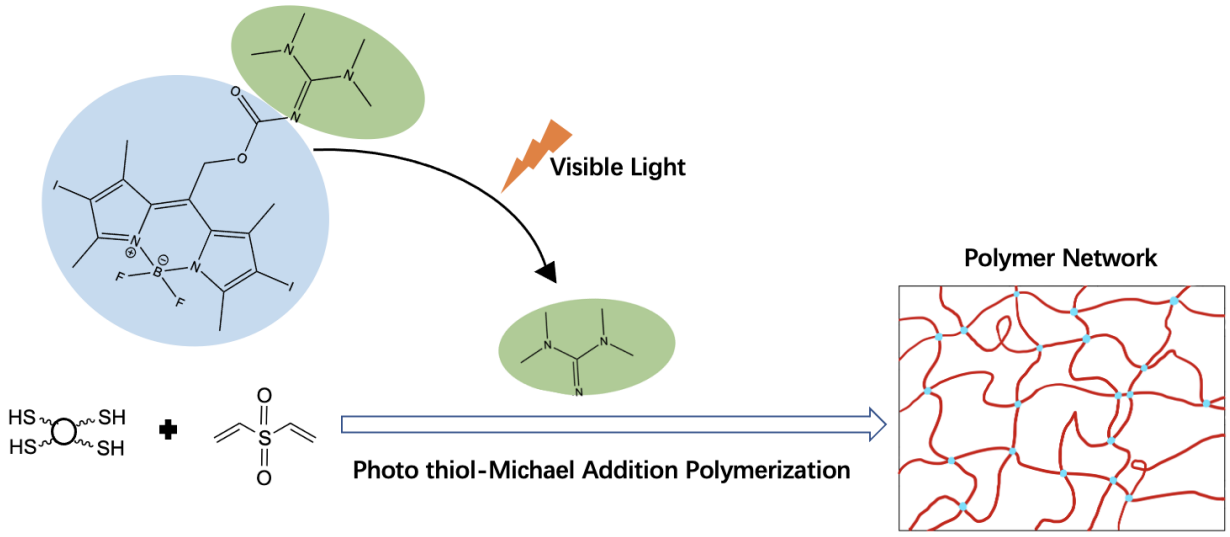

Figure 1: Visible–light initiated mechanism for photo thiol-Michael addition polymerization.

Nanoparticle Tracking Analysis of Polystyrene Particles in Blood Plasma

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Abstract: Targeted drug delivery utilizes nanoparticle-based drug delivery systems to efficiently deliver drugs in the body. This form of drug delivery increases the efficacy of the drugs and decreases unwanted side effects. This is especially important for diseases such as cancer where drug dosage is limited due to toxicity. However, nanoparticles face the obstacle of remaining in the bloodstream long enough to deliver the drug to the intended target. This is a consequence of being detected by the immune system and removed from the blood. Further, the interaction of the particles with the blood also increases the particle size due to the formation of a protein corona or aggregation of the particles, making the particles more easily detected by the immune system. The protein corona is formed by the adsorption of proteins onto the particle surface and can modify the physicochemical properties of the particle. This project aims to examine the thickness of the protein corona formed on differently structured Polystyrene (PS) particles in blood plasma. The addition of polyethylene glycol (PEG) to the particle surface, also known as PEGylation, is used to enhance particle circulation in the blood by decreasing interactions between the particles and blood components. Along with bare PS particles, this project also examined PS particles that were PEGylated with four different molecular weights of linear PEG (1, 5, 10, 30 kDa) and two forms of multi-arm PEG (4-arm 20 kDa; 8-arm 40 kDa). PS particles were PEGylated using an EDC/NHS coupling method. Solutions of the particles were made in either saline or bovine blood plasma. Nanoparticle Tracking Analysis (NTA) was used to measure the diameter of the particles in blood plasma and saline. The thickness of the protein corona was calculated using the following formula: (size in plasma – size in saline) / 2. The protein corona sizes of the linear PEGylated PS particles were not significantly different from the bare PS particles. The 8-arm PEG PS displayed the greatest decrease in protein corona thickness when compared to the bare PS. However, the results for the multi-arm PEGylated PS particles were not statistically significant and yielded high standard deviations. This high variability may be a result of the aggregation of particles over time. This determined that adding PEG to PS particles does not have a significant impact on the thickness of the protein corona. However, further research is required into using PEG of higher arm numbers as there is promise for multi-arm PEG to have a greater effect on protein corona thickness than linear PEG.

Investigating Platinum Nanoparticles for Cancer Treatment

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Abstract: According to the National Cancer Institute, cancer is among the leading causes of death worldwide and the number of both cases and deaths is expected to rise by millions by 2040. Platinum nanoparticles (PtNPs), however, have shown potent anticancer effects against various types of cancer cells while maintaining low toxicity in healthy cells. To further investigate PtNPs as a promising cancer treatment option, a platinum ion release study was performed to test if PtNPs work against cancer cells by releasing Pt^{2+} instead of increasing reactive oxygen species (ROS) in the cells, which is the current accepted hypothesis for PtNPs' mechanism of action. Therefore, the amount of Pt^{2+} released from PtNPs in PBS (pH 7) and MES (pH 5) buffers at several time points was recorded using an inductively coupled mass spectrometer (ICP-MS) (Figure 1). PBS simulates a healthy cell environment since it has a neutral pH while MES simulates a cancer cell environment since it has a more acidic pH. Furthermore, PtNPs' protein corona formation and aggregation behavior over 24 hours in bovine blood plasma were observed with nanoparticle tracking analysis (NTA). Protein corona refers to the set of proteins that attach to a nanoparticle's surface and is suspected to signal for a nanoparticle's removal from the body. Preliminary results of the release study indicate that more Pt^{2+} is released in MES for the first 24 hours, after which more ions are released in PBS and by 120 hours, there are cumulatively more Pt^{2+} in PBS than MES. Currently, the control and two more trials of the study are being tested. From the protein corona studies, by comparing PtNP size in water versus in blood, the protein corona was estimated to be 46.85 nm and the aggregation study results show that PtNPs form the most and largest aggregates at 14 hours (Figure 2). Overall, these experiments provide valuable information relevant to designing a safe and effective PtNP drug delivery system for cancer treatment. Future studies may include testing PtNPs with poly(lactic-*co*-glycolic acid) (PLGA), a common drug delivery system used to improve nanoparticles' circulation time, in blood and performing in vivo animal experiments with PtNPs.

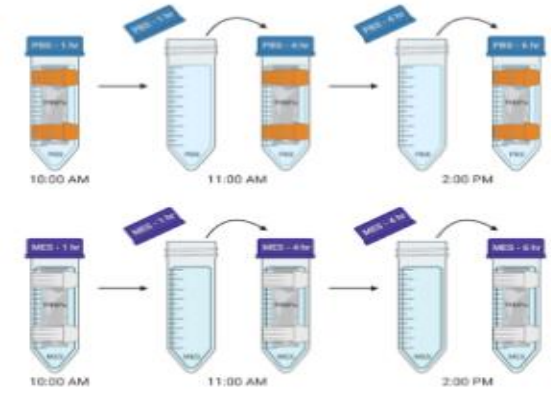

Figure 1: Sample Pt^{2+} release study setup

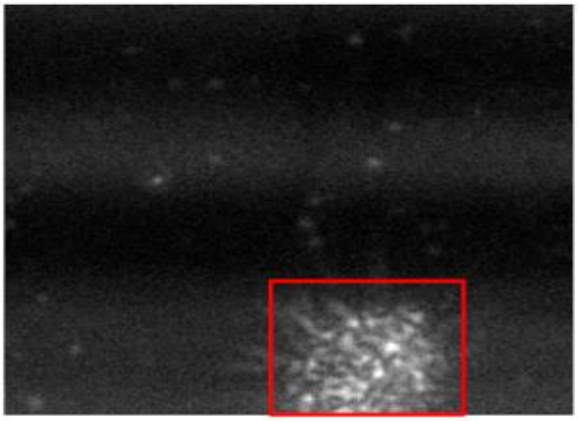

Figure 2: Sample PtNP aggregate on NTA (Created on BioRender.com)

Measuring Surface Tension in Silico by the Droplet Weight Method

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Surface tension is a key factor in determining the droplet formation and the behavior of liquid aerosols. We are specifically interested in aerosols formed by organophosphorus chemical warfare agents (CWAs), like sarin, in order to develop ways to decontaminate them. Due to the extreme toxicity of sarin, experiments at universities are not possible. However, one can consider its simulants: DMMP and DIMP. Their surface tension can be measured experimentally or predicted theoretically using molecular simulation[1]. The experimental approach focuses on droplet formation dynamics, while the conventional computational approach considers an equilibrated layer of liquid with a flat surface. Because of the different methods, a comparison between them is imperfect. Here we propose a new method for determining the surface tension of CWAs that more closely resembles methods used in experiments. In order to develop this method, a simpler system was considered: argon flowing through a graphitic tube. The formation of the argon droplet and its following separation were investigated. Even the preliminary version of the data analysis showed qualitative agreement with data from droplet weight experiments[1]. A molecular dynamics simulation was set up and run using LAMMPS[2] (Large-scale Atomic/Molecular Massively Parallel Simulator) and VMD[3] (Visual Molecular Dynamics). Data was visualized using OVITO[4] (Open Visualization Tool). A Python 3.9 script was used to analyze data from the simulation. Further research is required to test the new simulation method with more complicated liquids, such as water and alkanes. This study has significant implications in the field of defense, as this method gives the ability to determine surface tension for any liquid, regardless of toxicity.

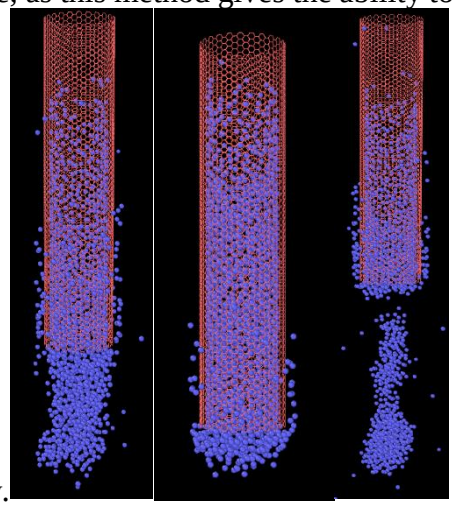

Figure 1: Droplet weight method in simulation

[1] Ivanova, E. V., Vasudevan, A., Senyurt, E. I., Schoenitz, M., Khalizov, A. F., Dreizin, E. L., & Gor, G. Y. (2022). Surface Tensions of Organophosphorus Compounds. (Submitted to J. Phys. Chem. Letters)
[2] Plimpton, S., Fast parallel algorithms for short-range molecular dynamics, J. Comput. Phys. 117 (1) (1995) 1–19.
[3] Humphrey, W., Dalke, A., & Schulten, K. (1996). VMD: Visual Molecular Dynamics, .J. Mol. Graph. Model., 14(1), 33-38.
[4] Stukowski, A., Visualization and analysis of atomistic simulation data with ovito–the open visualization tool, Model. Simul. Mater. Sci. Eng. 18 (1) (2009) 015012.

Literature Review and Data Analysis for Effective Vaccine Distribution

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In 2020, a global pandemic was declared effected by COVID-19, an infectious disease caused by the SARS-CoV-2 virus. There have been 88.4 million cases and 1.02 million deaths. It has not only affected the lives of individuals but there has been a huge allocation problem in many industries such as fashion, automobiles, agriculture, and more. With vaccinations created from Pfizer-BioNTech, Moderna, and Johnson & Johnson's Janssen, we are left with an allocation problem to distribute vaccines to all vaccination centers and meet their individual demands. Everyone eligible must get vaccinated. To ensure this, there must be an optimized and effective plan for vaccine distribution. This study provides a literature review and data on a newly-proposed optimization model that minimizes vaccine distribution costs under budget constraints. During my McNair Research program, I was able to assist my advisor Dr. Esra Buyuktahtakin Toy, and my mentor Elson Cibaku in their research project, which consists of proposing an optimized solution that minimizes transportation, fixed and penalty costs as well as the inventory cost of vaccine distribution. During this research program, we were able to collect data regarding the Vaccine Distribution Center (VDC) and Vaccination Centers (facilities) in New Jersey. The data was gathered from the Centers for Disease Control and Prevention (CDC vaccine.gov). Data collection consists of verifying the resources, validating the data, aggregating them, and generating them into a desirable format to be later utilized in the Vehicle Routing Problem for the Vaccine Distribution model (VRPVD). We collected the coordinates of each facility, the name of the vaccination center, demand of each facility, and the vaccine doses each facility offers. This tells us how the truck can get to each vaccination center and know how much vaccines to distribute. In cases where there is a shortage of vaccines, we can allocate the vaccines based on our equity constraint to ensure everyone gets a balanced number of vaccines. Also, my work consists of a literature review of several research papers. Through a detailed review of the current studies, I became familiar with the latest approaches and enhancements regarding the well-known combinatorial optimization Vehicle Routing Problem (VRP). The latest advancement for VRP and Travel Salesman Problem (TSP) are oriented toward learning algorithms and architectures that can be generalized to solving larger instances than the one used in training. For example, solving large-scale TSPs requires tremendous work with the neural network layers and learning patterns, which yields transfer learning to solve large-scale TSPs with zero-shot generalization. Another popular approach was deep policy dynamic programming, which combines deep learning and dynamic programming to get faster and more effective results for complex problems with larger instances. The future work emanating from this study will explore such learning algorithms to tackle the VRP problem.

Study of High Performance Fiber Reinforced Cementitious Composites

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Abstract: Concrete plays a very integral role in construction of civil infrastructure and related fields as the second most widely used material on Earth, by volume, after water. As construction projects continue to use concrete materials, engineers look to advance the science of concrete so that future societal needs in infrastructure sustainability and resilience can be addressed. One such need is addressing the design issues that come along with creating building and structures for areas that experience seismic activity. A class of materials known as high-performance fiber-reinforced cementitious composites shows promise in the face of this challenge. When structural systems are re-engineered with these materials, they exhibit a 40% improvement in seismic collapse probability and studies have shown that these composites provide strength and ductility increases of structural components. Although there are benefits when using these materials, their behavior under the combined effects of axial load and bending is not well understood. In this project, a comprehensive literature review was completed to investigate the failure performance of structural elements containing these materials. Then, a series of two-dimensional finite element models were used to simulate the response under axial loading and bending. The results of the computational simulations will be used to help in finalizing an experimental program that is part of large project funded by the National Science Foundation and slated to begin this fall.

Magnetically Augmented Variable Electronic Transmission (MAVET)

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Systems that use mechanical gears with teeth, such as windmills, gearboxes, and automotive transmission, all suffer from friction and therefore require maintenance and lubrication to function properly. Magnetic gears can eliminate these problems because they never actually directly interact with each other. When electromagnets are used instead of permanent magnets, we can then alter their behaviors, and therefore change gear ratios and the amount of power that can be transmitted. The MAVET system allows for a compact transmission with multiple gears to function with only the need for electrical power, using a series of inner and outer electromagnets that are connected to Arduino-controlled DPDT relays that can switch the direction of current through different coils. In order to come with a general design, research was done into general secondary gear systems, Magnomatic's Magsplit, and a mechanical variable transmission using permanent magnets. Creo Parametric was used to in order to model all of the different parts and assemblies. 3D Printers utilizing PLA, PVA, and PLA with iron particles. Future work for the MAVET prototype would be upgrading the power supply, making the electronics more compact and permanent, using thinner wire and larger coils, and lastly completing a patent.

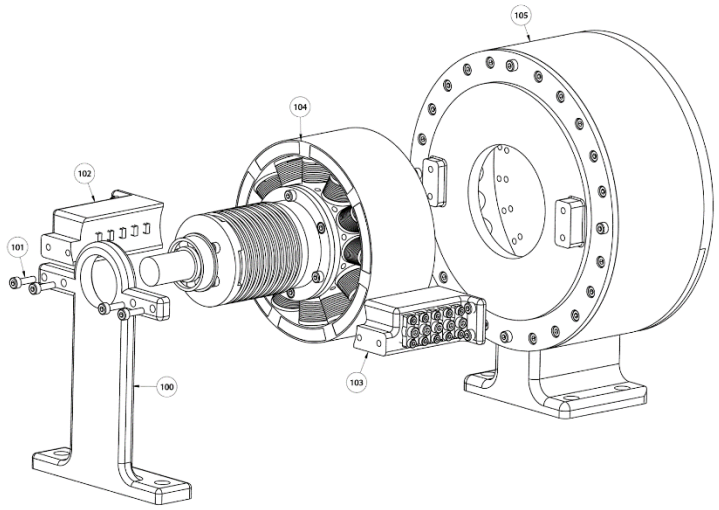

Figure 1: Exploded view of MAVET prototype's main subassemblies

Determination of the Threshold of Residue Hematocrit in Separated Blood Plasma Using Capacitance Measurements with Interdigitated Electrodes for Robust Biomarker Detection

Siddhant Jadhav

Microfluidics point-of-care biochips allow for the creation of biomedical devices which can diagnose various diseases, in a timely, streamlined and cost effective manner. Our prototype biochip can be used to measure various biomarkers. A drop of blood is deposited into the microfluidics plasma self-separation channel, from which the analyte of interest, plasma, separates. This analyte interacts with interdigitated gold electrodes, and the biomarker-electrode interaction builds up capacitance which can be measured using an LCR meter through a probe station. However, interference can arise from the effect of other elements and particles in the blood. For example, while a self-separation microchannel can separate the vast majority of the red blood cells, some leftover red blood cells can change the capacitance measurement. It is important to identify if such interactions cause a non-negligible effect on the capacitance signal, because this will interfere with the measurement of the target biomarker. An ideal range of hematocrit values where no issues arise with biomarker measurement, needs to be established. This range can be taken into consideration when further working on the plasma separation technology in the future. In the designed experiments, static drops of plasma solutions with varying hematocrit percentages were dropped on gold electrodes and the capacitance was measured using an LCR meter. This study helps further our understanding of the analyte-electrode interactions. This study is unique and novel in that it furthers our understanding of analyte-electrode interactions, paving the way for future development of better blood-electrode interface systems.

Integration of AI Assistance Toward Improving Human Performance in High-frequency Decision Making

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Abstract: While the use of artificial intelligence (AI) systems to automate tasks has become more widespread, there are still certain jobs where full automation is not feasible. In these scenarios, the implementation of an expert AI assistant can improve human performance while still maintaining human control. The goal of this project is to identify how different forms of AI suggestions can impact human performance in contexts requiring high-frequency decision making. This was done by creating a simple game environment where players balance a pole by moving a box side to side and using the Atari game, Breakout. During the game, players are presented with suggestions from a superhuman AI, such as which to move in, how likely the AI would take a certain action, and parts of the game environment the AI observes to decide what to do. Humans played multiple trials of the games with varying levels of AI assistance. Their performance was measured by recording how long each game lasted until the player lost. These times were averaged to compare how player performance varies depending on what form of AI suggestion is given. Our results identified that AI guidance can improve human performance when compared to playing with no assistance in these contexts. However, that performance declines as more complex information is presented to the player. In some cases, too much information can cause worse performance compared to having no assistance. These findings suggest that simplicity and ease of interpretability are more important for designing human-AI interfaces. Further work can be done to determine how AI assistance can be applied in other contexts. Furthermore, these results can help provide insight for designers to create interfaces that improve human performance while ultimately maintaining human agency.

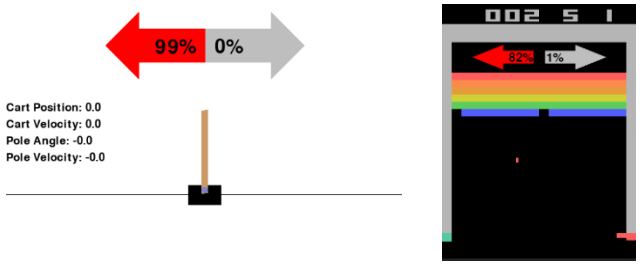

Figure 1: CartPole and Breakout game environments with AI suggestions

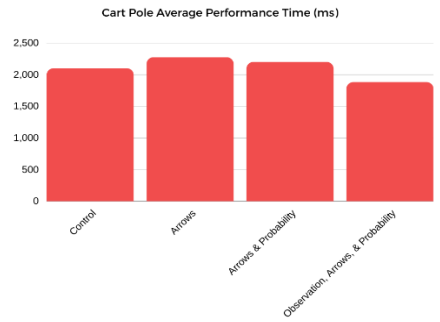

Figure 2: Comparison of player performance with different forms of AI suggestion in CartPole environment

Machine Learning Analysis of Turbidity Data from AguaClara Treatment Plants in Honduras and Nicaragua

Jacob Almanza

Two million people die each year due to lack of clean drinking water and waterborne diseases. AguaClara Reach is a nonprofit organization that strives to create and share better technologies to provide safe and clean tap water for small-scale communities. Beginning their process of rapid evolution in 2005, AguaClara plants are maintained and operated by members of local communities. AguaClara uses gravity to their advantage to mix and cleanse drinking water in their facilities as opposed to many mechanized water treatment plants. AguaClara partners with a network of researchers, implementation partners, and volunteers to develop their plant technologies. However, with less access to lab facilities and instrumentation, operators must run the plants with limited information. The main focus of water filtration at these plants is the measure of light scattering properties of water that stipulates the quality of the water, otherwise known as turbidity. In most cases, a high turbidity is an indication of increased solids, contaminants, or pathogens in water. The Environmental Protection Agency restricts turbidity levels to 0.3 Nephelometric Turbidity Units (NTU), while the World Health Organization only holds potable water to a maximum value of 5.0 NTU.

This paper outlines the use of Neural Network methods to help analyze data from multiple AguaClara water treatment plants. A main method used in this project is decision tree learning, which is the use of logic and conditionals to arrive to a predicted outcome. Through the use of sklearn's Decision Tree Classifier, the filtered water turbidity can be predicted from coagulant and chlorine dosage alongside the raw and settled turbidity measures. The neural network also features hyperparameter tuning using GridSearchCV. The outcome of the neural network outputs a confusion matrix that shows the predicted values compared to the actual values. The accuracy of the network is also shown. A test ran with turbidity data from the Moroceli treatment plant shows a 63% accuracy score and after hyperparameter tuning, a training score of 80% and a testing score of 67%.

Towards Real Time VLC: Indoor Angular and Euclidean Coordinate Localization Using Machine Learning

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Abstract: Technology-based companies use the global positioning system (GPS) to locate outdoor devices. This technology does not work well indoors. Therefore, there is a need to create a system that can localize devices or assets and use them to its advantage. This study planted retroreflectors on the machines and photodiodes placed on the light source. This system uses unmodified light to communicate the device's location to an algorithm in MatLab. This setup initializes the process of tracking the device's coordinate locations and detecting their orientation. This method is unlike using a GPS indoors because it includes a real-time backward channel to localize the device at the centimeter level at the exact moment.

Data values of the five powers were obtained by recording different coordinates. The several sample points appear arbitrary, and that is true. More samples mean better results. Keep in mind this depends on the regression method used. When collecting samples, unmodified light is retroreflected from the device containing a retroreflector. This power returns at the same angle of incidence (AOI) to a set of photodiodes. These are landmarks placed on a light panel. The power measured gets sent to a DAQ device and onto MatLab. Shutters were used to differentiating devices. Different regression methods were studied and used in training and testing models to predict the machine's localization better, and ECDF graphs were used as a result. The ECDF graphs obtained after the training demonstrated an accumulation of error that can be reduced with more sampling; however, some regression methods were better than others.

Designing a Predictive Model for Concussion Recovery

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Abstract: Approximately 3.8 million concussions occur every year in the United States. Of these cases, as many as 50% of concussions go unreported or undetected. In part, this is due to a lack of standardized diagnostic criteria, screening tests and tools for identifying signs and symptoms of concussions. Prior work led to the development of a diagnostic protocol and tool: the MoVES (oculomotor and vestibular endurance screening) protocol using the OculoMotor Assessment Tool (OMAT). At current, clinicians at the Virginia Neuro-Optometry group are collecting data from adult concussion patients undergoing vestibular therapy. Data is collected at multiple timepoints including the first visit and multiple periodic visits, until the participant/patient is completely recovered and symptom free.Therefore, the goal of the current project was to continue the longitudinal data collection using this novel protocol while developing a predictive model for recovery based on the trends present through this data.

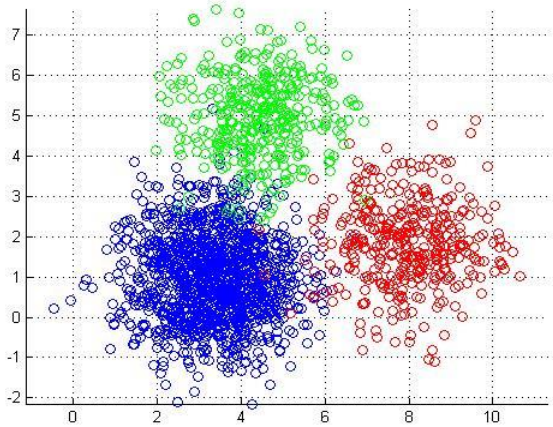

Figure 1. (PLACE HOLDER) Model Demonstrating High Sensitivity and Specificity

An assortment of clinical measures, risk factors, and participant characteristics were used in the development of sensitivity maps capable of aiding in the identification of key indications. Based on these metrics, machine learning techniques (regressions, classifications, and clustering) were tested to identify a model demonstrating high sensitivity and specificity. Next, this promising model will need to be tested following the collection of sufficient clinical data. Successful functioning would enable the model's predictive capability, allowing it to inform concussion recovery time, necessary recovery intervention(s), or recovery protration. While the ultimate goal of this project and its subsequent work is to improve concussion management, the establishment of such a predictive model can have applications across a variety of areas of interest. From estimating a heart attack patient's recovery time, to predicting whether a football player will recover before his Super Bowl, this can serve as a valuable tool for many different industries and populations.

Data Management for Physical Machine Intelligence

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Robot physical intelligence is much needed for robots to interact with the real world, though existing technologies are still at a primitive stage. Industries that benefit the most include medical (surgical robots), manufacturing (assembly lines), emergency management (search and rescue robots), and more. To further physical machine intelligence, crowdsourced motion data was obtained from human-demonstrations using a VR set and a motion sensor. The motion data was converted into high dimensional data describing trajectories (i.e., movements) in the state space, and then stored in the robot's knowledge library. For the robot to learn new trajectories from the demonstration data, nearest trajectory search is a fundamental operation that needs to be performed very frequently. Current issues brought forth by high dimensional data include their size, the resources (i.e., storage and computing power) required to solve queries with data of high dimensions and sustaining a constantly growing knowledge library. To overcome this challenge, we propose a discretization strategy that will help search for trajectories nearest to query points efficiently. Trajectories will be discretized into trajectory segments, then implemented into a graph-based searching algorithm to determine the nearest trajectories within the dataset. The proposed strategy should allow for more efficient nearest trajectory search, and further progress in the autonomous physical machine intelligence field.

Interactive Annotated 360 Environments for Educational Use (iXR Labs)

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Abstract: It often becomes difficult for educators to effectively teach their pupils about a given location or event without showing them said location in some way and oftentimes, it can be inaccessible to them for various financial, physiological, or logistical reasons. For example, if a country is war-torn or going through an epidemic. Many studies also support the fact that most students retain information better when it is presented visually/verbally rather than read directly from a textbook. The latter is not optimal for those students, who would be much more engaged in a more interactive and immersive learning environment. Our research proposes using a VR Application powered by the Unity Game Engine designed for the Oculus Quest to be used in educational settings as a supplementary learning aid. In this application, the educator provides a pre-annotated scene for the student to enter and interact with. There will be different key points where when a student interacts with them, a note will conveniently pop up on their wrist with the associated important information. The pre-annotated scenes will be generated from a CSV file with annotation and scene info provided by the educator. Upon start of the application, these files will be run through a CSV reader script we have developed in order to organize all the information and load all the annotations relevant to each scene on the screen. We have so far developed a base prototype application and successfully conducted usability testing through the use of an empirical study with various members of our lab who tested it and provided feedback via interview and post-use surveys. Future research and development would concentrate on creating a functional editor to make creating one's own scenes more accessible as well as updating the prototype to make it more dynamic.

Figure 1: Sample Application Infographic (Headset View)

ForensicXR

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Abstract: Staged crime scenes are essential for any Forensic Science student, as it allows them to get hands-on experience with Crime Scene Investigation (CSI) before entering the field. However, it can be difficult for students to access these staged crime scenes due to a variety of circumstances, such as COVID, tight schedules, or long commutes. This is exacerbated by the fact that a lab instructor must be present to run the staged crime scene for the student, and reset the scene after the student is done. With a full class of students, it becomes very difficult to make sure everyone has a chance to investigate the scene.

To solve this, we aimed to bring the scene to the student by scanning it and converting it into a VR application. To do this, a significant amount of time was put into establishing a consistent process for converting 3D scans of the scene into an object that can be used interactively in a VR application. There was also a feasibility study done on whether an upcoming technology, Nvidia Omniverse, would be able to assist in such a process. Ultimately, we found that it was possible to convert a 3D scan into a mesh object that can be imported into standard game engines, but we were not able to reach a sufficient degree of interactivity to facilitate a full VR app. As such, the scene was converted into an interactive level manually.

Another key component of the VR app was the tools that the student has access to during an investigation (e.g. UV lights, fingerprint brushes, cameras). We made use of gesture controls to provide a more realistic and intuitive way to use tools like the fingerprint brush, which require a specific “sweeping” motion in order to use properly. All of the tools were set up to create realistic reactions and outputs, which are all logged after the student is finished.

After the application was made, interviews were conducted with Faculty and Students at the NJIT Forensic Science department, in order to determine how accurate the application was to the original scene, as well as to identify areas of improvement. From these interviews we determined that while the gesture controls achieved an acceptable level of realism, the learning curve between a real staged crime scene and the digitized scene was too steep in some areas.

The result of this project is a prototype standalone VR application that allows students to investigate a recreation of the staged crime scene at NJIT’s Forensic Lab. Future work will center around reducing the learning curve, and making use of the generated logs in order to allow an instructor to view the student’s exact movements and actions so that they may give feedback accordingly.

Mapping and Understanding Animal Patterns through Simulated Environments

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Visualizing and understanding large sets of an animal's location data to see patterns is a difficult task. Along with this, the amount of knowledge regarding endangered animals is limited and this lack of understanding creates various problems for these animals. Over a large period of time, it takes extensive work to implement this data in an intuitive application that at the end is mainly understood by researchers in the field. Taking this data and making it digestible and dynamic would provide a system that allows for greater access to information. This research aims to create such a system in a Virtual Reality (VR) environment, to visualize, interact and better understand animal behavior through interaction. Implementing information relating to conservation efforts for animals, their common behaviors and dynamically presenting data is key to the application.

Using the Unity Game Engine, research and development was undertaken on how to visualize map information and dynamically adjust and display it in the VR environment. Using Microsoft's Bing Maps SDK for Unity, has made the process easy and streamlined. This allowed for the visualization of map data by using real-world latitude and longitude points to center a map, create anchor points to display a coyote and actively adjust the map based on data provided by The Wolf Conservation Center. By developing a CSV Reader script to accept data from a spreadsheet and convert it into readable data for Unity, we were able to utilize the SDK to then map points corresponding to an animal as well as displaying other necessary information. Essentially what was created was a baseline for future works to spawn from.

With this baseline, we ran an empirical study within our lab to determine the usability of the application and what potential uses can be gained from it. In creating an emotional impact, the application would serve well to have users better understand the importance of conservation and its efforts while connecting them with the animals. The system itself works well, however, interfaces can be improved to make a friendlier system. From this work, connecting it with data pulled from a web server and allowing for more civilian science applications would be the next steps in development.

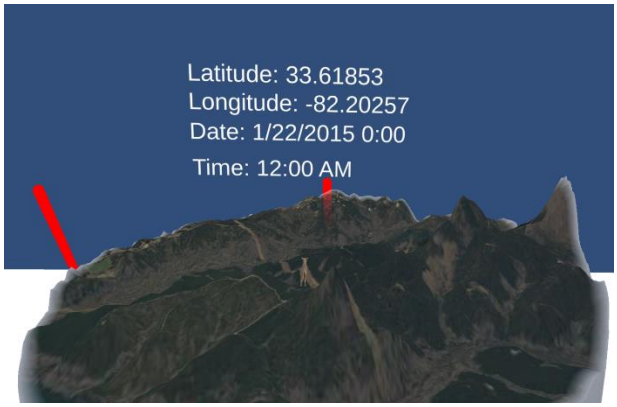

Figure #1: Application Screen

Toward a Behavioral-Level End-to-End Framework for Silicon Photonic Neuromorphic Computing

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Abstract: Convolutional Neural Networks (CNNs) are widely used due to their effectiveness in various AI applications such as object recognition, speech processing, etc., where the multiply and-accumulate (MAC) operation contributes to 95% of the computational time. From the hardware implementation perspective, the performance of current CMOS-based MAC accelerators is limited mainly due to their von-Neumann architecture and corresponding limited memory bandwidth. In this way, silicon photonics has been recently explored as a promising solution for accelerator design to improve the speed and power-efficiency of the designs as opposed to electronic memristive crossbars. In this work, we study the silicon photonics accelerators and take initial steps to develop an open-source and adaptive crossbar architecture simulator on top of Memristor Based Neuromorphic Computing System (MNSIM). We keep the original functionality of MNSIM and add a new photonic mode that utilizes the pre-existing algorithm to work with a photonic Phase Change Memory (pPCM) based crossbar structure. With inputs from the layout of neural network topology, the accelerator design configuration, and experimentally-benchmarked data, the proposed simulator can generate the optimal crossbar size, the number of crossbars needed, and give the estimation of total area, power, and latency. We next plan to evaluate and compare the performance of our adaptive simulator to the original MNSIM V1.1.

Process Optimization to Reduce Power in HfO2-Based RRAM devices for In-Memory Computing

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Abstract: In order to encourage the growth of artificial intelligence, the importance of neuromorphic technologies has grown. Memory systems need to be low power, non-volatile, multi-level cell (MLC), and able to artificially mimic synapses. This is where Resistive Random Access Memory (RRAM) technology has been theorized to play an important role. RRAM is a type of memory which uses the principles of resistive switching in order to represent data. RRAM technology in combination with SET and RESET voltage pulsing has been simulated in various studies to show the characteristics that would be important for neuromorphic technologies. This research aims to best optimize the process to make RRAM technology low power and MLC.

This research was conducted in three parts, one modulating the pulse widths with a constant pulse height to search for MLC characteristics, the second modulating the pulse heights with a constant pulse width to search for MLC characteristics, and the third seeking to test the level of degradation of the device over the course of 10000 cycles. The study involved four different RRAM metal oxide insulator materials including Hafnium Oxide, Hafnium Oxide with hydrogen plasma treatment, Hafnium Zirconium Oxide, and Hafnium Oxide with Aluminum Oxide. For the first part, after an RRAM device was formed at its given compliance current, a semiconductor analyzer was used to apply voltages with different widths including 4µs, 50µs, 1ms, and 10ms. Then the resulting conductance values were recorded. For the second part, an RRAM device for each material was also formed at its given compliance current. Then a semiconductor analyzer was used to apply a set of voltage pulses from 0.8 volts to 1.4 volts in increments of 0.1 volts. The third part of this study starts with each device being formed at its given compliance current. Then a voltage is applied for different pulse widths 10000 times. The time lengths include 4µs, 50µs, 1ms, and 10ms. Then the conductance data was recorded.

Once the conductance data from the devices were compared, the results showed that the Hafnium Oxide with the plasma treatment has better MLC conduction data as well as endurance data than the other devices. The next best results came from the Hafnium Oxide with Aluminum Oxide devices, then the Hafnium Zirconium Oxide. The Hafnium Oxide with no treatment showed the worst results. For the purposes of RRAM, the best material would be the Hafnium Oxide with the treatment, because it has the best MLC characteristics, the best endurance results, and would require less power since it has a low compliance current. The results also suggest that pulse width instead of pulse height is most suitable for MLC programming. Also, endurance data suggests that 50µs and 10ms pulse widths are most suitable for MLC programming. Going forward, this project recommends increased study into the field of RRAM devices. Some future paths of exploration include trying different metal oxide insulators, continuing to explore doping the RRAM devices, as well as increased testing to reduce variability and inconsistency.

Using a Webcam for Stroke Rehabilitation VR Games

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There is a need for home based rehabilitation of the hand for persons with stroke. The Rehabilitation Lab at NJIT is currently using the Leap Motion Controller to control a suite of rehabilitation games. While simple to develop with, the proprietary Leap Motion Controller © (LMC) is not perfect. It has a hard time reading the hand when near the boundary or close to the sensor. The goal of this project is to evaluate a replacement for the LMC, using a webcam and MediaPipe, a machine learning model by Google. MediaPipe is trained to predict absolute and relative x and y, and relative z, and can output in pixels or meters. Not only would there be potential for improvement but the removal of the hardware could also cut costs on the rehabilitation system and make it more accessible. The first goal is to develop a simple game to see the basic capabilities of the model. The second is to create a two camera setup for getting the missing z axis creating the 2 camera setup requires reverse engineering a function, and making it run well. Finally we will collect data from both cameras to quantitatively compare our web cam solution to the LMC. When collecting data, we recorded a video of the hands, and got the leap data in live time. Then we ran the video through the model to collect the webcam data. Finally, we imported the data into Matlab and translated to make up for the delay produced by pressing record. Shown below is a graph of the pinch distance as measured by both the LMC and MediaPipe. Both solutions produce an almost identical result, with well defined jumps when the finger opens and closes. The games evolved over time, but the end result was a beat saber-like game in which the player pinches spheres approaching synced to the beat of a song. The first iteration was made quickly, and was very unorganized. The second version had a far better code base, but was lacking a few key features like control over how many beats will appear. The final version was a basic hand rendering, with multi-camera support. For further research, it may be worth trying to improve the output. There is also a potential for a less intensive version that could also be researched. Developing a full game and testing it with patients is also a future possibility. Overall MediaPipe is looking very promising, and the graph below says it all, it's the same data in a lower cost and no hardware solution.

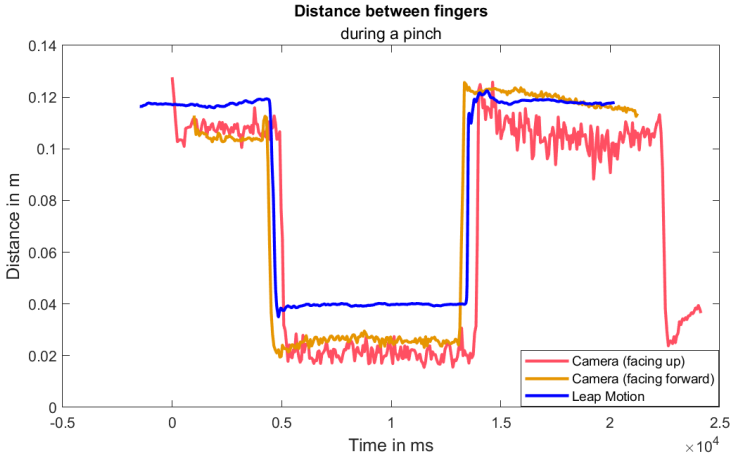

Figure 1: Pinch distance as measured by the camera and leap

Deep Learning Based Image Compression

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Abstract: The rapid growth of digital libraries and web-based applications has contributed to the rise in the volume of big data. Combined with an increase in media consumption, there is a need to develop data compression algorithms to optimize the use of network bandwidth and storage space. The motive behind data compression is to reduce the size of the data so that less space is required to store the data and less time is needed to transfer the data. However, it is challenging to keep the original features of the data once it is compressed as some of the information gets lost during the process. Moreover, compressed data must be decompressed for its original form to be analyzed and interpreted, which requires additional computational power. This project focuses on improving the performance of a specific image compression model known as an autoencoder. This model runs on Google Colab using the TensorFlow API. The model was modified by varying different hyperparameters, such as the code size, number of layers, and optimizer. The MNIST and Fashion-MNIST image data sets were used to train and test the model before and after modification. To evaluate and compare the performances, the mean squared error loss function was used. In comparison to the original, the modified autoencoder yielded greater error and required more runtime. The results signified that the added complexity to the autoencoder may have overfit the trained data set and thus did not perform as well on the test data set. Future work may implement other dimension reduction techniques to further improve the autoencoder.

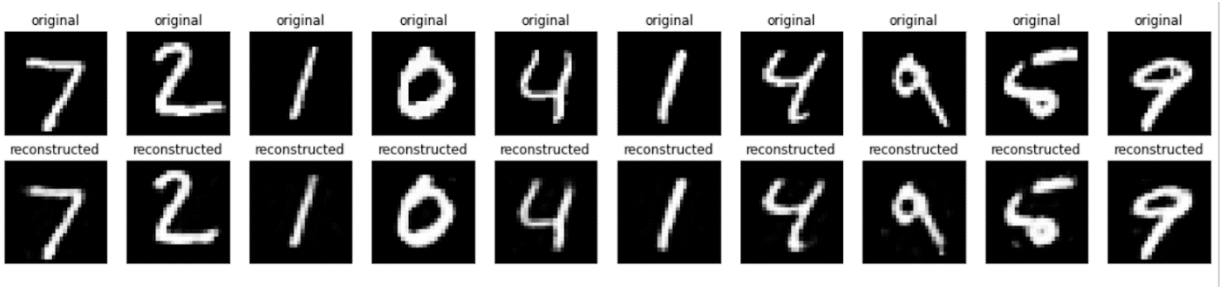

Figure: Resulting compressed images of the first ten images from the MNIST data set after running the test on the modified autoencoder. The mean squared error over ten epochs was 0.0700.

Machine Learning to Detect Fake News

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Abstract: Fraudulent news, or fake news, has proliferated because platforms such as Facebook, Instagram, Twitter, etc., allow users to instantly create and share false news headlines. Fraudulent news was particularly prevalent during the rise of COVID-19, with false claims about remedies, cases, vaccines, and more being widely shared. ("Garlic and vodka can cure COVID.") It is critical to be able to discern reality from fiction. To automate this process, we trained a machine learning model, called BERT, with thousands of fake and real tweets concerning COVID-19. This model is then used to categorize unseen tweets as fake or real. The tweets analyzed are all related to COVID-19 vaccines and are separated into two categories: posts from verified and from unverified Twitter accounts. The aim of this research is to determine the relationship between verified/unverified accounts and the rate at which fake and real news are detected from the two.

Using Convolutional Neural Networks to Classify and Predict Pneumonia in Pediatric Chest X-Ray Images

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There is an immense need for efficiency in the realm of medical diagnostics and image interpretation. We focused on using machine learning models to expedite the process of diagnosing cases of pneumonia in children from medical images. We utilized a data set containing chest X-rays from pediatric patients from a facility in Guangzhou, China. We sought to create a machine learning model that accepted chest X-ray images as an input to determine its ability to depict pneumonia with high accuracy. The model used for this study was the Convolutional Neural Network (CNN). Using Python 3 through the computing platform Jupyter Notebooks, we developed an algorithm that read in chest X-ray images and transformed them into numerical data points representing pixel color. We then divided the data into three different categories: 1) training set; 2) validation set; and 3) test set. We then trained a basic CNN, that served as a baseline and changed the architecture and hyperparameters to optimize the accuracy of the network. The networks built performed with accuracies greater than 90% on the training data and 70% on the test data. Our results show that CNNs are capable of accurately identifying pneumonia, and could have practical applications such as shortening the time it takes to diagnose pneumonia and leading to quicker treatments.

a. b.

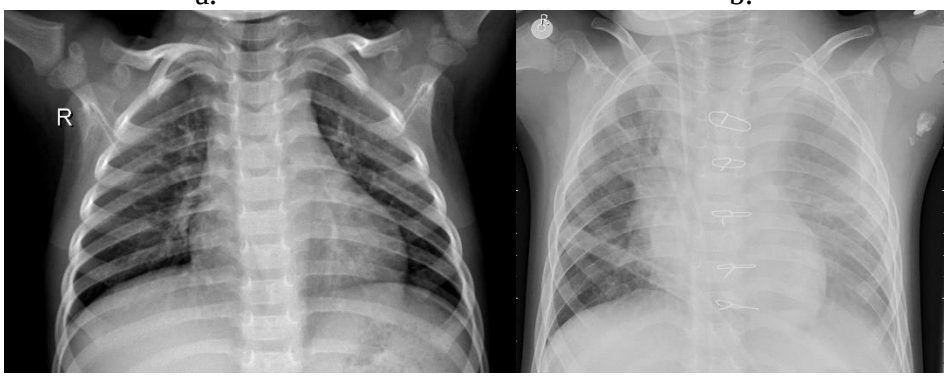

Figure 1. Chest X-rays depicting a. the normal state and b. pneumonia.

Security Evaluation of IoT Associated Medical Applications

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Abstract: The use of Internet of Things (IoT) devices for medical application is a surging practice where the demand moves ahead of the pace of proper security practices. IoT devices and the associated network architectures required to put these devices in practice create dynamic opportunities for attack. The suppliers of these devices and services tend to provide the minimum in terms of computational and security power so that they can maximize profit margins. This leaves security gaps in the system's architecture that can be exploited with malicious intent. There is a need for non-profit investigation of the security status of medical applications and their associated network architectures. This work will take a glimpse into the current state of app security with a focus on apps harboring sensitive medical information to draw suggestions for future users. The methodology from previous works will be leveraged as a way to investigate each app. The types of user data that is at stake with each app will be categorized by required and optional. A variety of attack vectors focused on the mobile application, cloud endpoint, and communication vulnerabilities will be analyzed. The stakeholders responsible for mitigation techniques will be outlined as well to give an idea of the next step to take. Ten different medical applications with visual, audio, heart monitor, and general health purposes will be reviewed. This work is unique among previous work done in the field that does not have a medical and IoT focus. This work seeks to raise awareness on the increased danger of cyber attacks and their ever present opportunity.

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