Michigan Technological University

Undergraduate Research Symposium

2021

Welcome to the 2021 Undergraduate Research Symposium!

The Undergraduate Research Symposium highlights the amazing research being conducted on Michigan Tech's campus by some of our best and brightest undergraduate students. While we aren't able to hold an in-person symposium this year, we still want to celebrate our students and faculty with this compilation of abstracts and an online exhibition of narrated posters.

The students showcased at this year's Undergraduate Research Symposium have worked alongside Michigan Tech faculty and graduate students to explore, discover, and create new knowledge. They've spent long hours in the lab (virtually and in person) or out in the field testing hypotheses by designing experiments or creating new models, gathering data, analyzing that data and contextualizing it with the broader literature. They've applied their classroom knowledge in new and sometimes unexpected ways, and developed new skills that will propel them forward in their careers.

Each student was mentored by a faculty member who took great care to guide them through the trials, errors, and successes of research. Through the process, they've built strong relationships that will last a lifetime. I'd like to thank our faculty, our sponsors who have funded much of the work you'll see in this exposition, the office of the Vice President for Research for originally creating and funding the Summer Undergraduate Research Fellowship (SURF) program, and the Portage Health Foundation, the DeVlieg Foundation and the Michigan Space Grant Consortium for funding the Undergraduate Research Internship Program (URIP).

We miss the opportunity to celebrate our students in person at the Undergraduate Research Symposium. But among the many things we've all come to appreciate over the last year is the importance of the researchers, the ideators, the analysts, and the problem solvers. Take a few minutes to delve into the research that's happening every day at Michigan Tech. If you have questions, reach out to the students over email - they'd love to talk about their work. And imagine the impacts that these young researchers are going to make throughout their careers as they create a bright future.

Adrienne Minerick
Interim Dean, Pavlis Honors College

Michigan Tech

Pavlis Honors College

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The Odyssey of a Baffle System, an Extruder Malfunction, and Unprintable Material

Student Presenter: William Acevedo, Management and Materials Science & Engineering
Faculty Advisor: Joshua Pearce, Materials Science & Engineering

Introduction:

COVID-19 has affected everyone in some way, shape or form. Most of us have suffered in the air we breathe and questioning how clean it truly is… At the MOST lab, we wanted to create a baffle system that would filter the air around you for you to breathe purified and fresh air. It first started with the designing 3D printed baffle, then printing it with the best material suitable for such a thing which at the time was Ninjatek Ninjaflex. But due to a change in manufacturing the Ninjaflex, the skin of the filament wasn't extruding any material, thus bringing the research to a pause. Then with the help of NinjaTek and Lulzbot Associates we worked through finding the next best material if Ninjaflex was no longer going to work even with having tried countless troubleshooting procedures. Then the NinjaTek Cheetah was reincarnated to be our savior. With the same results as the previous no longer manufactured Ninjaflex, the Cheetah brought the mission to filter man's air back to life. Once the printer was functional again, we got back to printing a perfect piece to then be able to test chemically. It took many tries, but it luckily produced a decent piece before the bed's glass chipped and made the printer no longer functional again. Time later, we received a newer model bed and got back to work in testing for one last time if a perfect print was possible. So we'll find out. If the print goes well, then people will be able to have their own personal filters at their workplace, school, and home.

Materials and Methods:

Creating a baffle through modeling that would filter air and be of precise dimensions. Printing out such baffle by correcting measurements and possible ways of being printed out. Working through errors, troubleshooting, and unpredictable results. Chemically testing and treating final baffle. Rating results and testing usability.

Results and Discussion:

So far, we've reached being able to print a decent print. We are still currently testing the baffle chemically and depending on whether that succeeds is whether we can make more of them using the Cheetah filament. That also brings us to where we are now in testing 1) that we can print an even better baffle (if it needs changes in the modeling file or the gcode itself) 2) that the filament will work.

The Effects of Morning vs. Pre-Sleep Mindfulness Meditation on Sleep Health, Mindfulness and Anxiety

Student Presenter: Thomas Basala, Human Biology
Faculty Advisors: John Durocher and Brigitte Morin, Biological Sciences

Introduction:

Meditation smartphone applications are now readily available to anyone who owns a smartphone, allowing a wide range of people to benefit from the sleep benefits of mindfulness meditation and potentially improving the sleep health of many people. Many meditation apps have different programs that are tailored to be used right before going to sleep, but there is no research data to support that the sleep specific programs improve sleep more than a program that can be taken at any time of the day.

Materials and Methods:

In this study, we will focus on how meditating in the morning versus meditating before bedtime affects metrics of sleep health (total sleep time, sleep onset time, number of sleep awakenings, etc.) as well as mindfulness, decentering, and state anxiety. We will collect baseline sleep metrics including sleep quality, sleep onset time, sleep efficiency, total sleep time, and a pain score using an actigraphy watch. Baseline data from a State Anxiety Trait questionnaire, a Five Facets of Mindfulness questionnaire, and a Decentering questionnaire will also be collected. The orientation will include each eligible participant receiving a Philips Respironics Pro actigraphy watch which will be worn for a four-day baseline recording period in addition to all questionnaires being completed. Following the baseline recording period, participants will participate in one, four-day meditation intervention period (morning or night) where the same data collected in the baseline recording period will be collected. When we complete our data collection our first step will be to run normality tests on our major dependent variables. If the data is normally distributed, we will utilize a repeated measures ANOVA with 3 conditions (baseline, morning meditation, evening meditation) with sex as a between-subjects factor. When there is a significant "condition effect" we will then use paired t-tests to make direct comparisons across two conditions (ex. baseline vs. morning, or morning vs. evening). If there is a significant condition x sex effect, we can then use paired t-tests to compare across conditions with men only, or women only (SPSS allows us to easily do this procedure). If data does not have a normal distribution, we would use a log transformation on that variable before running the ANOVA.

Results and Discussion:

Creating a research study that puts participants through a meditation regimen at different times of the day (i.e. morning vs. night) and collecting data pertinent to sleep quantity, sleep quality, and additional mindfulness, anxiety, and decentering questionnaires would provide novel data regarding the effects of time-specific meditation and could offer insight into improving meditation interventions aimed for improving sleep health. The results of this study may be significant in creating a better understanding of how meditation can be used as a non-medicinal sleep aid and may spur further research into the effects of how meditation impacts sleep.

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Analysis of the Labor Market & Landscape of 1900 Lake Linden French Canadians

Student Presenter: Brooke Batterson, History
Faculty Advisor: Sarah Fayen Scarlett and Mark Rhodes, Social Sciences

Introduction:

How did ethnic identities affect social and spatial mobility among late nineteenth-century immigrants to the Upper Peninsula? In 1867, Joseph Gregoire arrived from Quebec and started one of the most successful lumber mills in the Keweenaw, drawing many French Canadians to come work for him in Lake Linden. During a previous research project conducted during Spring and Summer 2020, I identified and mapped the immigration of these families from St Jean province, Quebec to the Keweenaw. I continue to follow this group of people through time and space, investigating which families stayed in Lake Linden, their occupational choices after the sawmill ceased operations in 1885, and where they chose to live. By tracing descendants through archival records and the physical landscape, I discovered that the second generation diversified their jobs and moved throughout Lake Linden all while remaining closely aligned with the culture of previous generations.

Materials and Methods:

The project began with conducting background research through further reading on the subject of French Canadians and the lumber and mining industries. Once an appropriate amount of background knowledge was obtained, the Michigan Tech Archives were assessed for the purposes of tracking down the descendants of the Gregoire lumber mill workers and discovering where they lived and worked in the year 1900. The categories used to compare workers are general labor, lumber, mining, agriculture, white collar, and other. In 1880 it is clear that more workers were employed by the lumber industry while in 1900 there's a shift to more general labor. Due to limited access to records during the pandemic, the category of general labor may include those working within the lumber industry. The 1900 census, the Lake Linden City Directory, and familysearch.com were used to both find descendants and discover where they worked and lived. Those still residing in Lake Linden were then mapped using ArcGIS in order to discern any particular pattern.

Results and Discussion:

The sample does not appear to show any obvious patterns in housing. The changing occupations of various workers over time, however, shows that social mobility is more vertical in nature than horizontal. Based on background research involving French Canadians, it was expected that more workers would be involved in the lumber industry, but the data clearly shows that this group held many different positions ranging from white collar work to manual labor. The results show that the most popular category of work for this ethnic group was general labor which supports the conclusion that these workers and their families were incredibly flexible with regards to the rapidly changing landscape and labor market while still retaining their strong ties with their heritage. New roles adopted by individuals still kept with long held attitudes about labor. For example, employment with mining companies encompassed operations above the surface, staying consistent with general labor patterns of French Canadians that have been observed by other researchers.

Determination of Heats of Atomization and Heats of Combustion of PAHs via Accurate Quantum Mechanical Model Chemistries

Student Presenter: Steve Beuther, Chemistry
Faculty Advisor: Loredana Valenzano-Slough, Chemistry

Introduction:

The description of the physical-chemical properties of single molecules at the electronic structure level is of paramount importance for the understanding of the formation and assembly of particulate matter in various environments and under different thermodynamic conditions. With this in mind, this project aims at the quantum chemical determination and extrapolation of thermodynamic properties such as heats of formation and heats of combustion of Polycyclic Aromatic Hydrocarbons (PAHs), whose existence and influence on their chemical surroundings span from the origin of Life in the interstellar medium to their formation in the Earth's atmosphere as the consequence of anthropogenic combustion events.

Materials and Methods:

The quantum mechanical based Gaussian16 software package was adopted. Single molecules geometries were collected from the NIST PAHs Database and/or built through the GaussView and the Avogadro graphical interfaces. Relaxation geometries and frequencies calculations were performed to obtain the necessary thermochemical results (vibrational zero-point energy, thermal energy contribution (T=298.15 K), and enthalpy). Composite model chemistry methods such as complete basis set methods (CBS-QB3) were adopted. Results obtained at the CBS-QB3 level represents the benchmark of comparison with respect to results obtained with the use of more approximated level of theories (density functional theory -DFT) such as the B3LYP functional in combination with the Pople 6-311G, and the Dunning aug-cc-pVDZ, and aug-cc-pVTZ basis sets. Following a clustering data mining approach, results were analyzed to identify patterns and trends able to then be used to extrapolate accurate energies for larger PAHs such as pyrene C16H10 and benz[de]anthracene C17H12 , starting from values referring to smaller species such as benzene C6H6 and toluene C7H8.

Results and Discussion:

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Refining the Quantification of Carbon in Forested Soils

Student Presenter: Grady Boyle, Forestry
Faculty Advisor: Evan Kane, Northern Research Station

Introduction:

Loss on ignition is the most widely used way to measure soil organic carbon. This process uses a broad conversion factor of 0.5 to convert from the combusted organic matter to organic carbon. Evidence has shown that this conversion factor grossly overestimates some soil types and genetic horizons carbon content. This is especially evident in the soil order Spodosols where we hypothesize that the conversion factor broadly overestimates carbon in the spodic horizons. We hypothesize that the formation of spodic horizons is the cause for this overestimation, likely due to a higher rate of metal complexation than carbon occlusion in these soils.

Materials and Methods:

A dataset was formed using the ISCN database. From this, 269 profile samples were found from 11 states with 530 individual horizon samples that had Carbon data and loss on ignition data. Data is now being run through a variety of statistical modeling techniques to find correlations between C:LOI ratio and a variety of factors, such as depth, horizon, and pH.

Results and Discussion:

Upon initial analysis, patterns show that carbon to loss on ignition ratios are lower within the b and c horizons of Spodosols averaging a conversion factor of 0.305. This leads us to believe that with further modeling we may find an overall statistically significant difference between the conversion factors for this soil type. Further, we expect to find links between certain genetic horizons and these lower conversion factors that may offer insight as to the mechanism that is causing these lower C:LOI ratios.

Characterization of Aqueous Two-Phase Extraction Systems for Virus Purification

Student Presenter: Ethan Burghardt, Biochemistry
Faculty Advisor: Caryn Heldt, Chemical Engineering

Introduction:

Current techniques for large-scale vaccine production are hindered by low yield and throughput and were designed to purify proteins. Aqueous two-phase extraction (ATPE) is a technique that draws viral particles harvested from a cell broth across a fluid interface into one phase, while leaving protein and DNA impurities behind. Viruses vary in size and surface characteristics, requiring extensive development to purify each vaccine or gene therapy candidate. An understanding of the driving forces of ATPE allows for prediction of appropriate systems and potential additives to purify specific viruses. This work primarily investigated the fundamental mechanisms of virus transfer across the interface during ATPE.

Materials and Methods:

Polyethylene glycol (PEG) with an average molecular weight of 12 kilodaltons and sodium citrate solutions were prepared at 40 and 35 (w/w%) respectively. The sodium citrate solution was neutralized using 3.0 molar citric acid. Using deionized water, aliquots of each component phase were diluted to concentrations specified using a binodal curve, ultimately producing 500 gram ATPS. This binodal curve was generated in previous work, using the turbidity method. Tie lines at tie line length (TLL) 12, 22, and 32 were determined by measuring the conductivity of the citrate phase. Identical systems were prepared so they include 0.45 molar betaine and glycine. Each system was homogenized for 60 seconds at 500 rpm using a stir bar/plate and was transferred to a separatory funnel. The systems were then allowed to settle for 72 hours to ensure complete phase separation. Interfacial tension was measured using the Du Nouy ring method on a force tensiometer. The ring probe was cleaned with detergent, acetone, and flamed between trials. The interfacial tension of water was used as a standard and measured in between trials to ensure that the ring probe had been cleaned sufficiently.

Results and Discussion:

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Durotactic Migration of Cancer Cells on Engineered Scaffolds

Student Presenter: Mitchell Connon, Biomedical Engineering
Faculty Advisor: Smitha Rao, Biomedical Engineering

Introduction:

Biophysical cues are an important focus of study in the proliferation, viability and metastatic behavior of cancerous cells. The rigidity, or stiffness of the extracellular matrix in the cancer cell microenvironment can affect the migration [1]. Here the role of mechanical stiffness together with a known topography of acellular synthetic scaffolds on cell proliferation, migration, and tumor progression for wound healing and cancer research is presented. Since, 3D-cultures offer advantages over 2D culture in closely mimicking the microenvironment of a cancer tumor, in vitro study of cell-cell and ECM interactions in conditions similar to the tumor environment is made possible.

Materials and Methods:

Here we evaluate the durotactic behavior of a cancer cell in response to stiffness. To mimic the body tissue, acellular synthetic scaffolds having aligned nanofibers were fabricated and characterized. The mechanical properties were assessed using dynamic mechanical analyzer (DMA), while the surface chemical properties were determined using Fourier transform infrared spectroscopy (FTIR). The fiber alignment and diameter were characterized using field emission scanning electron microscopy (FE-SEM). Standard cancer lines from renal, lung, and breast tissues were seeded on the fibers to analyze the cell morphology, viability, and changes in proteins that regulate cell survival, tumor formation and cell-cell adhesion. Immunocytochemistry was used to qualitatively analyze cell morphology and cell-scaffold behavior. Cell Titer BlueTM was used to assess cell viability.

Results and Discussion:

Aligned nanofibers obtained by varying the rotational speed of the collector were obtained. The diameter of the fibers varied according to the collector speed and thereby affected the mechanical stiffness of the overall nanofiber scaffold. We've previously reported that the nanostructure makeup of the fiber scaffolds affects cell proliferation and alignment [2]. Similarly, it has been reported in literature that cancer cell proliferation is impacted by the stiffness of the substrate. Here, we established differences in cell proliferation on scaffolds of different stiffness for standard cancer cell lines from breast, kidney, lung tissue. Based on our work, it is clear that further investigation of the nanostructures and the microenvironment impacting cancer growth needs to be investigated. The information obtained has the potential to affect cancer drug screening, such as preference of secondary targets and gain a better understanding of cancer cells migration and cellular responses.

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[2] "Engineered three-dimensional scaffolds modulating fate of breast cancer cells using stiffness and morphology related cell adhesion," Samerender Nagam Hanumantharao, Carolynn Que, Brennan Vogl, Smitha Rao, Preprint available, https://ieeexplore.ieee.org/document/8954754/media#media.

SURF

Understanding the Trends in Physical Activity via the Use of Activity Trackers With and Without the Use of the UNICEF Kid Power Program Among Rural Elementary Students

Student Presenter: Sarah Dix, Exercise Science
Faculty Advisor: Kelly Kamm, Kinesiology and Integrative Physiology

Introduction:

Children in rural areas are more likely to be obese than their urban counterparts. Given our rural communities, it is important to find interventions which promote physical activity among children. UNICEF Kid Power is an online platform that provides interactive videos for physical activity. The primary objective of this study is to determine the impact of the UNICEF Kid Power program on physical activity, measured as change in mean daily movements over a 7-day period (week 2 v. week 5) in children ages 6-10 years old in Baraga County, Michigan.

Materials and Methods:

This study is a randomized, controlled trial. Treatment arm assignment will be determined by block randomization (blocks of 4). Participants will be actively involved in data collection for 5 weeks. 50 children will be enrolled in the study; 25 in each arm (control and intervention). To begin the study, Fitbit Inspire 2 activity trackers will be mailed to each participant after enrollment and completion of a baseline survey. Prior to mailing, a Fitbit account will be set up for each tracker. Although the tracker can collect additional information, the only data recorded by the study team will be daily movement (steps), duration of physical activity (min), and the number of hours each day between 8 am and 8 pm with 250 or more steps (hourly activity). Every 5-7 days data will be recorded in the study record by participant ID. Data will be accessed through the API Fitabase system. At the end of week 5, all participants will be sent an endline survey.

Results and Discussion:

This study is a randomized, controlled trial. Treatment arm assignment will be determined by block randomization (blocks of 4). Participants will be actively involved in data collection for 5 weeks. 50 children will be enrolled in the study; 25 in each arm (control and intervention). To begin the study, Fitbit Inspire 2 activity trackers will be mailed to each participant after enrollment and completion of a baseline survey. Prior to mailing, a Fitbit account will be set up for each tracker. Although the tracker can collect additional information, the only data recorded by the study team will be daily movement (steps), duration of physical activity (min), and the number of hours each day between 8 am and 8 pm with 250 or more steps (hourly activity). Every 5-7 days data will be recorded in the study record by participant ID. Data will be accessed through the API Fitabase system. At the end of week 5, all participants will be sent an endline survey.

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Open Source Gentle Ventilation

Student Presenter: Nicki Gallup, Biomedical Engineering and Mechanical Engineering
Faculty Advisor: Joshua Pearce, Materials Science and Engineering

Introduction:

When COVID-19 first hit, and hit hard, people began to panic and chaos ensued. Many people were getting sick and we were running low on medical devices. With the MTU Open Source Technology Research Lab, we thought about a few ways we could help as many people as possible. One idea was to create an open source gentle ventilation system for those who may not have the funds or access to hospital resources. This gentle ventilator could be created from common household items and a basic understanding of electronics, making it accessible to millions of people all over the world.

Materials and Methods:

The main hardware components of the gentle ventilator were all 3D printed, making this available to anyone that has access to a 3D printer. There is a mouthpiece that is connected to the pump via tubing. The tubing can be purchased online. The electronics involved requires basic soldering skills. An Arduino Nano was used for the pump control, as it is the easiest to integrate into any system, and can be connected to a transistor to provide an input source. A single momentary switch is also used to signal the Arduino to switch pressure states. The feedback of the system is a PWM (pulse-width modulation) signal to minor the output of the switching device. For the short-term use of this device, a breadboard or perfboard will be implemented alongside the power supply of DC 12 volt. A calibration of the pressure device was used to determine the amount of pressure the gentle ventilator could safely apply to a patient. Many tests were conducted in order to identify if any inconsistencies occur along the device from the pump to the mouthpiece for two hours at 10-minute intervals.

Results and Discussion:

It was found that there was a significant pressure drop between the pump itself and the mouthpiece. The pressure drop was inconsistent at each test due to leakage of air. This could be due to the tubing attachment not secured as properly as it could be. This can be fixed by updating the 3-D printed attachment for the tubing or adding adhesive around the edges to further secure the tube itself. The design is still a work in progress where various improvements can be made to the overall pump design. A potential update is to create a new design of a gentle ventilator that is not as harsh on the lungs of the patient with a softer flow of air from the system itself. Also, we could make the device more adaptable and accessible for those who might have a difficult time accessing the Arduino or electrical components. This can be adapted when updating the design to be more accessible for the patient.

DeVlieg Foundation

FEM-based Force Reconstruction Method for Fast and Accurate Traction Force Microscopy Application

Student Presenter: Samuel Haarman, Biomedical Engineering and Mechanical Engineering
Faculty Advisor: Sangyoon Han, Biomedical Engineering

Introduction:

Traction force microscopy (TFM) is a soft-gel-based assay used to measure the spatiotemporal distribution of the traction forces exerted by a living cell. TFM software uses the bead images, taken with and without cell presence, to calculate a displacement field then reconstructs traction out of the displacement. For the force reconstruction, a forward relationship between force and displacement needs to be established, for which the boundary element method (BEM) has been exploited by current force reconstruction methods. However, BEM usage is inherently limited to a flat, continuous, and elastic gel configuration. To extend the TFM's application toward non-planar substrates, a novel algorithm using the Finite Element Method (FEM) was developed and compared with the existing methods for accurate traction estimations.

Materials and Methods:

TFM-FEM operates similarly to the previously used FastBEM in terms of regularization/noise reduction and post-processing. However, the two methods differ in the mechanics of their respective solution calculation. Conventional FastBEM makes use of the Boussinesq solution which operates in a homogeneous, infinite half-space by integrating over the area of a distributed unit force. The results of this integration are then used to solve the inverse problem and determine the traction force based upon the calculated displacement. FEM-based force reconstruction utilizes the same distributed unit force, but calculates the solution using finite elements. In order to verify the efficacy and accuracy of the FEM reconstruction, a collection of bead images were simulated using an FEM-based technique. One simulation consisted of a single force application area with a diameter of 40 nm and force magnitude of 500 Pa. The other consisted of ellipse shaped force application areas of various magnitudes and directions placed in a cell-like configuration. The resulting simulated displacement was then applied to the original bead images to obtain a pair (deformed and undeformed). The images were analyzed to obtain the displacement field which was again used to reconstruct the traction field using FEM-TFM, FastBEM and FTTC. Additionally, experimental bead images of the gel on which PtK1 cells were cultured were also analyzed to further compare the three methods.

Results and Discussion:

It has been found that in the multi-force condition, FEM-based force reconstruction produces similar force reconstruction magnitudes and resolves the force application area closely compared to the original and the other methods. In the case of the single-force condition, FEM-TFM appears to produce more uniform results that more closely match the curvature of the original traction map when compared to the FastBEM and FTTC methods. Due to the nature of the FEM-TFM solution, expansion into three dimensions is attainable by using bead image stacks and interpolating the force reconstruction results at bead locations within the substrate. This would allow for the investigation of cell traction forces on patterned substrates such as microgrooves. A future direction is to apply the FEM-TFM method to a soft nano-topology substrate and elucidate the mechanical understanding through which induced pluripotent stem cell-derived cardiac muscle cells mature better on such substrates.

DeVlieg Foundation SURF

Development of Furuta Inverted Pendulum Test Rig for Testing of Motor Dynamics and Capabilities

Student Presenter: Justin Henderson, Mechanical Engineering
Faculty Advisor: M.K. Park, Mechanical Engineering

Introduction:

Biomimetics is a popular topic in the robotics world due to the potential solutions that varying methods of mobility can give. Emulations and combinations of existing natural systems have been found to increase mobility and efficiency in related terrain. However, due to the complex dynamics of these systems, thorough dynamic evaluations of actuators are crucial to attaining the desired result. This study aims to gain information on motor dynamics for future implementation of hip and/or knee actuators in wheeled legs. This is achieved through control theory, simulation, integration of control hardware with actuators, and the validation of a desired test.

Materials and Methods:

This study focuses on using a Furuta inverted pendulum to validate motor dynamics, which uses the rotation of the motor and attached arm to maneuver a freely hanging pendulum into an upward position and balance it for a prolonged length of time. This method is chosen over a classical inverted pendulum due to the use of actuators as rotational joints in a robotic leg. The dynamics of the motor and arm will relate to joint and leg control much closer than linear movement.

Determination of related equations of motion allows prediction of motion for the system in the physical world and provides the necessary information to perform simulations. Determination of control hardware and software is achieved through feasibility, compatibility, and ease of use. Simulink is used to simulate the system in addition to sending motor commands via serial connection. For motor control, state feedback is utilized so that optimal motor behavior can be adjusted via manually selecting poles.

Testing of the system will consist of logging the physical movement and comparing it to simulation results of the same maneuver. When the motor can stay within restrictive voltage bounds while achieving a high positional accuracy, the test will be considered successful.

Results and Discussion:

Determining the capability of the actuator to perform a Furuta inverted pendulum test is estimated to establish a detailed mathematical understanding of the dynamics of the motor and the performance of the controller designed for the particular motor. Integration of control hardware packages with simulation in addition to proper simulation configuration has proven to be the most complex work of this study. Discovery of inherently compatible hardware and software has expedited the process of success. We expect this research to serve as a fundamental base of the actuators that could be extended to implementation of joint actuators in a wheeled leg system.

Mechanochemical Comparison Between Hydrogel and Silicone Gel Used for Studying Stiffness Sensing by Adherent Cells

Student Presenter: Kathleen Heusser, Biomedical Engineering
Faculty Advisor: Sangyoon Han, Biomedical Engineering

Introduction:

Extracellular matrix (ECM) stiffness induces differences in cell spreading via sensing by cell-ECM (extracellular matrix) adhesions. Cells' increasing spreading in response to increasing stiffness has been established based on studies using hydrogels such as polyacrylamide gel. However, on the high refractive-index silicone gel, referred to as Qgel, such a cell spreading phenotype has not been recapitulated. Cells on the soft Qgel have still shown a large spread area with also large traction. In this study, via characterization of both gel types, I provide evidence that the surface hydrophobicity of Qgel dominates cell response over the ECM stiffness.

Materials and Methods:

Polyacrylamide (PAA) hydrogel was synthesized on acid washed coverslips using a mixture of acrylamide and bisacrylamide at different ratios, which yielded different stiffnesses. Qgel920 from Quantum Silicones was synthesized with different ratios of components A and B to manipulate stiffness. Contact angles were photographed using an apparatus in Dr. Jeffrey Allen's lab (Mechanical Engineering-Engineering Mechanics), and the images were analyzed using ImageJ software to quantify the contact angles for each gel. Plasma treatment, which established that the contact angle (hydrophobicity) of Qgel can be easily adjusted, was performed for this experiment by Mohanish Chandurkar with permission of Dr. Paul Bergstrom. Gels' attractive capabilities (stickiness) and stiffnesses were measured with the help of Dr. Fei Long (Mechanical Engineering-Engineering Mechanics) via Atomic Force Microscopy. Storage moduli (G') for Qgel's stiffness spectrum at all mixing ratios was quantified using the HR-2 hybrid rheometer in Dr. Faith Morrison's lab (Chemical Engineering). Cell spreading experiments will involve the use of NIH 3T3 fibroblasts, which I will image via fluorescence microscopy.

Results and Discussion:

I fabricated PAA and Qgel at varying stiffnesses and tested several properties. First, rheometry tests over the range of Qgel mixing ratios (1:1 - 1:2) produced stiffness values within a range similar to PAA. Secondly, however, contact angle measurement showed that Qgel (120º-130º) was more hydrophobic than PAA (20º-30º). This suggests that the effect of surface hydrophobicity on cell adhesion, thus on spreading, potentially contributes to inconsistency between literary PAA and laboratory Q gel results. Interestingly, I also found that while Qgel remained consistently hydrophobic across multiple stiffnesses, PAA showed inverse correlation between stiffness and hydrophobicity; the higher PAA stiffness, the lower its contact angle. Atomic force microscopy (AFM) showed huge attractive force (stickiness) from Qgel. Via bovine serum albumin (BSA) treatment, I could adapt Qgel's surface charge, obtain a flat baseline, and estimate Young's moduli from force-displacement curves. Attractive force and elastic modulus quantification is in progress. Future experiments will utilise plasma treated Qgels and untreated Qgels to test how hydrophobicity affects cell adhesion and spreading, independently of stiffness. This will determine whether plasma treatment, by decreasing hydrophobicity, allows cells to mimic PAA gel: spread increasing with stiffness. I anticipate that hydrophobicity dominates cell spreading and adhesion.

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Radial Basis Function Generated Finite Difference (RBF-FD) Method for Solving Partial Differential Equations (PDEs) over Evolving Curves and Surfaces

Student Presenter: Caleb Jacobs, Applied Computational Mathematics
Faculty Advisor: Cécile Piret, Mathematical Sciences

Introduction:

There are many numerical methods for solving partial differential equations (PDEs). However, few methods exist to solve PDEs on evolving surfaces. Evolving surface PDEs arise in a number of engineering and medical fields; they can be used to model the stresses over a bending plane wing, the growth of a tumor, or to analyze data from medical imaging equipment. The most prominent methods for solving PDEs on evolving surfaces either converge too slowly and have poor performance over complex geometries or they have a difficult setup. Our method requires very little setup and yields high convergence rates.

Materials and Methods:

To develop and test our method, we have proven baselines such as the Orthogonal Gradients Method (OGR) and the Closest Point Method (CPM) to compare our results to. In order to compare our method, we have selected a number of test problems such as the merging circles problem, the dumbbell problem, and a few others. Our method was developed using both theoretical (on paper) and numerical (implemented in a programming language such as Julia or MATLAB) means. Due to the complexity of Radial Basis Function Generated Finite Differences (RBF-FD) based methods, theoretical proofs of validity are hard to come by and so, we verified the validity of our method by producing numerous convergence plots in solving the test problems listed above. Our method is based on RBF-FD, which allows us to work without a mesh. To use RBF-FD on an evolving surface and to derive true solutions to the test problems, we use Ricci Calculus with the tensor formulations of the surfaces.

Results and Discussion:

To develop and test our method, we have proven baselines such as the Orthogonal Gradients Method (OGR) and the Closest Point Method (CPM) to compare our results to. In order to compare our method, we have selected a number of test problems such as the merging circles problem, the dumbbell problem, and a few others. Our method was developed using both theoretical (on paper) and numerical (implemented in a programming language such as Julia or MATLAB) means. Due to the complexity of Radial Basis Function Generated Finite Differences (RBF-FD) based methods, theoretical proofs of validity are hard to come by and so, we verified the validity of our method by producing numerous convergence plots in solving the test problems listed above. Our method is based on RBF-FD, which allows us to work without a mesh. To use RBF-FD on an evolving surface and to derive true solutions to the test problems, we use Ricci Calculus with the tensor formulations of the surfaces.

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Traumatic Injury Prevention: Validating a Novel High-Impact Online Intervention

Student Presenter: Bailee Kimbel, Psychology
Faculty Advisor: Erich Petushek, Cognitive and Learning Sciences

Introduction:

Knee injuries are the most common season/career ending sports injury and about 80% of these injuries require surgery. Research shows that the strongest modifiable risk factor for ACL injury, other than sport of choice, is whether an athlete engages in Neuromuscular Injury Prevention Training (IPT). This ACL injury prevention neuromuscular training has been shown to reduce ACL injuries by 50%, yet it is not used as often as it could be. Many coaches know that knee injuries can be problematic, but they lack the knowledge and skills to prevent these types of injuries.

Materials and Methods:

The overall goal of this project is to increase the capability and motivation of various stakeholders (e.g., coaches, parents, athletes, etc.) to implement IPT. The central hypothesis of this project is that a brief educational intervention will improve comprehension and motivation to implement IPT. We tested this hypothesis by evaluating the effectiveness of a brief educational intervention using a 3-arm randomized control design. We randomized the participants (60 total) into three groups - one viewing the brief animated video, one reading a standard informational web-based text (WebMD), and a control group viewing an educational video about concussions. Each group took the pre-intervention survey about ACL prevention knowledge and skills. Then they watched and read their respective materials, and then took the survey again. In addition, following the brief intervention we asked participants regarding their likelihood of implementing IPT.

Results and Discussion:

The results of this project show that coaches who watch the animated video improved their ACL risk and mitigation comprehension by twelve percent, while the control group showed no change at all ($p<.001$, Cohen's $d = .84$ – large effect). This data shows the ability to successfully implement a web-based randomized control trial. This also suggests that coaches who watched the animated video were more likely to implement an ACL IPT with their athletes, compared to the control group coaches. It also shows that the coaches who watched the animated video thought implementing an ACL IPT would be feasible, while the control group did not ($X2= 17.6$, $p= .001$). As we continue this research we will discover if our data supports the hypothesis that educational intervention will improve comprehension and motivation to implement IPT, not only for coaches, but athletes and the general public as well.

DeVlieg Foundation

Optimization of Wave Energy Converters Through Neural Networks

Student Presenter: Morgan Kline, Mechanical Engineering
Faculty Advisor: Gordon Parker, Mechanical Engineering

Introduction:

Wave energy converters (WECs) are devices that convert the kinetic energy available in large bodies of water into useful electrical energy. This conversion occurs when there is relative motion between the drag plate and buoy component of the WEC. Though most of this energy is stored, a control strategy can be implemented to release small amounts of energy back into the generator at opportune times to maximize energy extraction. A crucial component in this control strategy is the ability to predict future excitation force. This research aimed to use a neural network implementation to predict these forces.

Materials and Methods:

Simulated wave field and buoy data were available for this project. Provided was wave displacement, buoy displacement and wave excitation force measurements to train and evaluate several neural network architectures to estimate the force applied to the buoy from incoming waves. The networks were built to accept these measurements as inputs to predict future excitation force as the output. The use of both buoy and wave data mirrored the available data that can be seen in a common WEC array setup.

Several network types were explored and created throughout this study, including a NARX net, NAR net, LSTM network, and a Time Delay (also known as a nonlinear input-output) network. Additionally, both linear and nonlinear buoy response regimes were explored. This exploration was useful in determining each network's reliability during more challenging, as well as less challenging conditions. Results of the networks were tested by comparing the predicted output and target output data to calculate percent error.

Results and Discussion:

Of the explored networks, it was determined that the Time Delay network was best, as it had the fastest run time and an error response between 10e-03 and 10e-07 percent, for highly nonlinear and linear simulated data, respectively. However, this is an ongoing study that continues to raise questions regarding the implementation of neural networks on WEC optimization and the most effective ways to utilize them. Some relevant topics that require further investigation include the effects of wave reflection within the wave tank and its effect on the validity of the network, as well as the most ideal arrangement of inputs within the network to produce an optimally trained network.

This research resulted in the development of a wave force measurement system that will be deployed to MTU's Wave facility in March 2021. This system uses a linear actuator to dynamically position a buoy in a wave field while measuring the vertical force on the buoy, as well as the corresponding position and speed of the buoy. In conjunction with existing wave gauges, this apparatus will permit experimental validation of the technique developed by this SURF project.
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SURF

Engaging Under-Resourced College Students in the Western Upper Peninsula

Student Presenters: Anderson Lind and Jada Markham, Management and General Business
Faculty Advisor: Jon Leinonen, College of Business

Introduction:

In rural regions like the western Upper Peninsula, under-resourced students face a myriad of issues beyond the average student. Our research has resulted in a list of recommendations that could be researched further toward implementing within the Copper Country area to provide support for under-resourced students. We are currently focusing on researching and establishing a sustainable Promise Program for students pursuing higher education in the Copper Country.

Materials and Methods:

We began our research by examining common issues that under-resourced students faced with some examples being: worrying about food insecurity, finding transportation to and from campus, and their familial support not understanding the college application and financial aid processes. While determining how to help students, another issue arose: rural communities often faced less access to federal and state resources. We then met with campus and community leaders to determine relevant solutions for improving students' experiences, both during the application process and after they've reached their institution. After compiling our findings into a report, we sent the report to all contributing community leaders and gathered feedback.

Results and Discussion:

Based on our conclusions drawn through research, we offer several recommendations to support under-resourced college students grouped into two categories: 'University' and 'Community & Foundation'.

At the 'University' level we recommend: implementing a secondary education ambassador program, region-specific scholarships, student phone app to navigate all aspects of college life, expanding the Ombudsman services, and providing additional faculty and staff training to support under-resourced students.

At the 'Community & Foundation' level we recommend: implementing a college transition counselor, creating a Promise Program, and improving students' health assessments.

Along with these recommendations, we encourage collaborative dialog among the secondary school systems and universities to identify specific and coordinated goals, as well as target outcomes to better serve all aspiring college students of the western Upper Peninsula.

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Assessing the Accuracy of a Social Collaborative System for Explainable Artificial Intelligence

Student Presenter: Hunter Malinowski, Computer Science, Psychology
Faculty Advisor: Shane Mueller, Cognitive and Learning Sciences

Introduction:

As artificial intelligence systems are becoming more capable, they are becoming increasingly more difficult to understand. This has led to development of Explainable AI: systems for helping users understand how and why an AI system works. One approach to this is to rely on human users to collaboratively explain AI systems to one another. However, it is important to know whether collaborative explanations generated by novice users are likely to provide correct and accurate information about the AI.

Materials and Methods:

To assess the accuracy of a database of collaborative explanations about AI, we first identified 58 statements generated by a user community regarding two image classification systems, unitized into 113 independent codeable statements, establishing agreement by two independent raters. Of these, 95 statements about the target system and 18 foil statements based on another AI classifier, so that they would be legitimate statements but not correct about the target system, were selected. Then, we defined a set of inclusion criteria to establish how many of the codeable statements included verifiable assertions about the AI, resulting in a total of 97 (18 foils and 79 targets) such statements. Finally, each statement was coded based on whether it was correct, incorrect, or partially correct by two independent raters.

Results and Discussion:

Results indicated that independent raters could achieve a high level of agreement on the cases, (weighted kappa=.76). Of the 18 foils, 11 were judged by both raters as incorrect, and only 1 as correct. Of the 79 target statements, the coding resulted in a total of 66 statements judged correct by both raters, and only 1 as incorrect, with the remaining 12 judged partially correct by one rater and either correct, incorrect, or partially correct by the other. Results show that two raters can accurately identify known incorrect and correct statements, and that surprisingly, a group of users can work together, through a collaborative tool, to share accurate explanations about an AI system they are mostly unfamiliar with.

Exploring the Effects of the Emerald Ash Borer on C Cycling in Ash-Dominated Wetlands

Student Presenter: Alayna Merten, Statistics
Faculty Advisor: Fengjing Liu, Forest Resources and Environmental Sciences

Introduction:

The expansion of emerald ash borer (EAB) across the Great Lakes region is threatening ash-dominated forests, particularly black ash wetlands. EAB induced ash mortality will likely affect carbon (C) cycling due to the increased light availability and temperature and changes to hydrology. Changes to soil C quantity, quality, and respiration can provide insights into how ecosystem processes might be changing. The objective of this study is to quantify soil C pools and fluxes at black ash wetlands in MI and MN and to utilize C isotopes to assess changes to C cycling as a result of simulated EAB infestation.

Materials and Methods:

The simulated EAB sites in both MI and MN have multiple plots with a different treatment applied to each, Control, Girdle, or Ash Cut, simulating wetlands unaffected by the EAB and wetlands 3-5 years post-EAB infestation, and wetlands completely altered by EAB, respectively. Soil respiration was measured bi-monthly from June-October from 2012-2014 at sites in both states. Soil samples were collected in 2014 and 2019 from 6 sites in MI and 6 sites from MN, both 3 of each treatment. Volumetric soil samples were collected at 3-5 points in each site to capture within site variability in soil. Soils were kept on ice in the field and then oven dried and homogenized. To prepare the sample for the lab the soil was grinded in the ball mill, then weighed and placed in tin capsules. The samples were sent to the LEAF lab where they were tested for organic carbon concentration and stable isotopes (13C). Using ANOVAS 0-10 cm deep soil samples from both MN and MI were analyzed. Mixed effects models were used to analyze CO2 gas fluxes using date previously collected from MN experiment sites.

Results and Discussion:

The results of the two-way ANOVA with state and treatment as factors for soil C stocks of 0-50 cm deep samples was that there was no significant difference between soil C stocks in MN or MI or between the Control and Girdle treatments. Soil δ13C isotopic signatures ranged from -27.1 to -29.1‰, suggesting that the soil C originated from relatively undecomposed, fresh plant material. The initial results (not all samples have been analyzed) of the two-way ANOVA with state and treatment as factors show no significant difference between soil C stable isotopes in MN or MI or between the Control and Girdle treatments. Using linear mixed effects modeling and a significance level of 5%, CO2 gas fluxes were significantly higher at the Ash Cut sites than the Girdle or Control, and significantly higher at the Girdle than Control sites. LME model conditional r2 = 0.4207, with optimal LME model including soil temperature at 5 cm depth, water table level, treatment as fixed effects, and gas collar location as a random effect. The higher soil respiration rates at the disturbed sites, suggests that some additional process, possibly an increase in highly labile fine roots, was stimulating microbial activity at these sites.

Community Response to Renewable Energy Project Siting: A Case Study in L'Anse, MI

Student Presenter: Ava Miller, Sustainability Science and Society
Faculty Advisor: Richelle Winkler, Social Sciences

Introduction:

This project aims to understand community response to a proposed wind generation project in L'Anse, Michigan, focusing on the role of community engagement in the decision-making process, why the community opposed the project, and ultimately why it failed. Understanding why communities oppose renewable energy project sightings is critical for improving the siting process that will be necessary in the transition to clean energy sources.

Materials and Methods:

The project is a qualitative case study and methods include content analysis of documents, meeting minutes, websites, and letters to the editor related to the proposed project, as well as 5-7 interviews with community members and leaders. So far, 55 documents have been coded for key themes using a grounded theory approach. Categories and relationships found in the data are used to explicate and refine a story of the observed phenomenon by using storylining. By doing this, we can formulate and test theories related to the community's reasoning to oppose the wind project.

Results and Discussion:

Preliminary findings suggest that people opposed turbine development because it ran contrary to their idealized vision of rurality and nature in a remote forested area (a "pristine wilderness"). Turbines and associated road and infrastructure development were seen as a source of industrialization directly threatening the rural idyll. Initial findings also suggest that early community engagement was limited, lacked transparency, and was driven by the developer. This resulted in lack of trust in the permitting and governance process. Justice concerns around tribal sovereignty, despite the challenge to treaty rights associated with potential disruption to hunting and gathering opportunities on ceded territory, further fueled opposition and distrust. Ongoing interviews seek to address these issues in more detail.

Effects of Cell-Specific Optogenetic Stimulation in the Subthalamic Nucleus for the Treatment of Depression

Student Presenter: Tessa Mlinar, Biological Sciences
Faculty Advisor: Chunxiu (Traci) Yu, Biological Sciences

Introduction:

Deep brain stimulation (DBS) is a clinical therapy for Parkinson's disease (PD). The subthalamic nucleus (STN) is a widely used target and has been proven clinically effective for the motor symptoms of PD. However, the clinical effects of STN DBS on depressive symptoms of PD are still controversial. The STN received direct input from depression suppression area-medial prefrontal cortex (mPFC). However, whether selective modulation of STN neurons leads to the behavioral effects of STN DBS in depression is still unknown. It remains unclear which subdivisions of the STN are responsible for the depressive effects of STN DBS.

Materials and Methods:

The virus-based, cell-selective anterograde tracing study was conducted to delineate the depression-related substructure of the STN. Viral vector AAV5-CaMKII-GFP was injected into the mPFC. After allowing four weeks for viral expression, the brain tissue was harvested, sectioned, and imaged by fluorescent microscope. The behavioral study began by inducing depression. One group was injected with viral vector AAV5-CaMKII-Chronos-GFP into the STN and an optical fiber implanted in the medial ventral subdivision of the STN. The second group was used as control to examine the timing effect on depression. After one recovery week, rats underwent the Chronic Mild Stress (CMS) Protocol to produce chronic depressive behavior. The rats were exposed to three or four stressors during the day for four weeks. The stressors included loud noise, wet cage, tilted cage, restraint, stroboscopic illumination, and inversion of light/dark cycle. After completion, the rats were assessed for depressive behaviors using force swimming test (FST), sucrose splash test (SST), and sucrose consumption test (SCT). After confirming depressive symptoms, optogenetic DBS was conducted for 2 hours before the second FST, SST, and SCT tests.

Results and Discussion:

An exploratory study was conducted to ensure that our proposed CMS protocol was effective in inducing depression. We confirmed animals developed moderate decreases in sucrose preference, a sign of anhedonia, and an obvious reduction in FST mobility after 4 weeks of CMS. After properly inducing depression in a new group of animals, we conducted optogenetic DBS. Our data show that optical DBS in STN increased sucrose preference by an average of 12% and increased the animal's percent time grooming by an average of 13%. Further, there was an average 6% decrease in swim mobility following CMS, which was improved by an average of 12% following DBS. These increments in sucrose preference, grooming time, and swim mobility provide valuable insight that DBS is capable of reversing the effects of CMS in rats and thus being a potential treatment for depression. We are currently in the process of analyzing histological data to confirm the specific connections between mPFC and STN. The research for this project is still ongoing, the results so far show promising information that could be used in future testing.

Microbial Diversity in Marine Sediments

Student Presenter: Luke Moore, Biochemistry and Molecular Biology
Faculty Advisor: Stephen Techtmann, Biological Sciences

Introduction:

Marine sediments are home to a vast array of microbes and are estimated to contain over 1029 cells. The genomic analysis of marine microbes will aid in the identification and understanding of their metabolisms, ecological roles, ancestry, and possible biotechnological applications. Seafloor anomalies like mud volcanoes and hydrocarbon seeps are areas of interest because of the diverse micro- and macrofaunal communities that are fueled by chemolithotrophic microbes like methanogens and carboxydotrophs. These mud volcanoes can expel carbon monoxide, carbon dioxide, and methane which can support diverse microbial metabolisms.

Materials and Methods:

This study is aimed to characterize the taxonomic and functional diversity microbes present in sediments from two different marine environments. The first is the Mediterranean Sea which has a high salinity (~39 psu) and a higher deep-water temperature than most ocean environments (14 °C in Mediterranean deep water compared to ~4 °C in many other deep-water settings). The second is the Caspian Sea which is a brackish water body, with anoxic deep water. Genomic analysis of samples using shotgun sequencing was conducted alongside 16S rRNA gene analysis to obtain the taxonomic and functional profiles of the sediment microbial communities.

Results and Discussion:

We hypothesize that there will be distinct microbial communities in sediments obtained from mud volcanoes compared to other sediments and that the microbial communities in the mud volcanoes will have shared metabolisms fueled by the gases emitted from these mud volcanoes. We are particularly interested in characterizing the diversity of organisms that encode the carbon monoxide dehydrogenase (CODH). The CODH is the key enzyme in methanogenesis (methane production), acetogenesis (acetate production) and carboxydotrophy (carbon monoxide consumption). The aim is to be able to understand the genomic diversity of these environments and how chemolithotrophic metabolisms are distributed in marine sediments and mud volcanoes.

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Evaluating Novel Biodegradable Stent Materials at a 1-Month Time Point

Student Presenter: Lea Morath, Biomedical Engineering
Faculty Advisor: Jeremy Goldman, Biomedical Engineering

Introduction:

Conventional metal stents remain in a treated artery for the lifetime of the patient. The permanent presence of foreign material is associated with harmful side effects. Bioresorbable stents that provide mechanical support during the healing phase and then harmlessly degrade may avoid the long-term side effects. The goal of this study is to evaluate the biological and immunological response to the implantation of different bioresorbable zinc alloy compositions for stenting.

Materials and Methods:

An *in vivo* rat arterial implantation model will be used to evaluate the biocompatibility of four zinc alloys and their thermal treated counterparts. The explants were collected at one month and will be cryo-sectioned and histologically stained with H&E and VVG. Each cross-section will be measured for base neointimal length, protrusion of the implant into the lumen, and neointimal area to characterize the in vivo response. Explants will also be fluorescence-labeled to identify the number of macrophages and smooth muscle cell distribution.

Results and Discussion:

The anticipated outcome is finding an alloy that performs better mechanically and biologically than pure zinc or the industry standard, platinum.

Osteoconductive Electrospun PCL β-TCP Nanofibers

Student Presenter: Emily Nelson, Biomedical Engineering
Faculty Advisor: Smith Rao, Biomedical Engineering

Introduction:

Electrospun nanofiber scaffolds made of biodegradable materials have found application as bone scaffolds facilitating bone healing. Polycaprolactone (PCL) is a commonly used polymer in nanofiber scaffolds. Osteogenic inorganic materials such as betatricalcium phosphate (β-TCP) increase osteoconductivity and aid proliferation of bone cells. [1] [2] [3] Through this research I sought to understand cell adhesion, proliferation, and alignment on PCL β-TCP scaffolds and the parameters required to produce bone healing scaffolds.

Materials and Methods:

Nanofiber synthesis using electrospinning depends on the composition of the sol-gel used. Our group has previously reported PCL nanofibers of honeycomb, aligned and mesh morphologies for cell culture applications.[4] However, the reported work did not consider addition of β-TCP for bone scaffold application. Here, parameters were established to successfully electrospin PCL fibers with β-TCP integrated within. Characterization of the morphology was done by visualizing the fibers with FE-SEM to quantify fiber morphology, diameter, and alignment.

In vitro characterization using the mouse-derived osteoblast precursor MC3T3 cells were carried out. Cell viability assays and immunostaining was used to compare cell proliferation and growth on PCL β-TCP scaffolds compared to PCL fibers. Degradation of the PCL β-TCP fibers was studied and compared to the degradation of PCL fibers. A Dynamic Mechanical Analyzer (DMA) was used to characterize the mechanical properties of the scaffolds both before and after degradation. The surface chemistry of the fibers was analyzed using Attenuated Total Reflection-Fourier Transform Infrared Spectroscopy (ATR-FTIR).

Results and Discussion:

Through this study, we expect to have developed a nanofiber scaffold that includes the biodegradable material PCL and an inorganic substance β-TCP that will support bone cell alignment and proliferation. Following the identification of the parameters for electrospinning, it was observed that humidity affects the fibers produced. Cell adhesion and proliferation appears to be affected by fiber morphology. Further studies into specific morphologies and concentrations of β-TCP need to be carried out to develop a long-term solution. Lastly, in order to support bone cells, the mechanical strength of the polymers used needs to be higher. In the future, polyvinylidene difluoride (PVDF) will be considered as the starting polymer to create the nanofibers.

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Spectral Indices Detect Changing CO2 and CH4 Cycling in Response to Hydrological Stress in Sphagnum Dominated Northern Peatlands

Student Presenter: Ally O'Neill, Applied Ecology and Environmental Science, Wildlife Ecology and Conservation
Faculty Advisor: Evan Kane, Forest Resources and Environmental Science

Introduction:

Peatland ecosystems not only store more carbon than all of Earth's forests, they also play a large role in the balance of carbon dioxide and methane, two potent greenhouse gases. As the climate warms, it is likely that peatlands will experience altered rainfall and lowered water table patterns, which in turn will alter CO2 and CH4 cycling. Remote sensing technology may be able to detect these changes in greenhouse gas cycling as hydrology in northern peatlands is altered.

Materials and Methods:

In this study, we evaluated multiple spectral indices and their ability to detect changes in CO2 and CH4 cycling in two Sphagnum-peatland mesocosm studies in which water table depth and rainfall quantities were manipulated, along with the vascular and non-vascular plant community composition.

Results and Discussion:

Spectral indices of greenness (Normalized Difference Vegetation Index, Chlorophyll index) and water content (Water index, floating Water Band Index) were effective at detecting peatland water content and water table alterations, with all indices declining significantly as a function of dryness. Declines in these indices were correlated with reduced CO2 uptake and reduced CH4 efflux, which are heavily influenced by hydrology in Sphagnum-dominated peatlands. This study suggests that remote sensing indices can be used to evaluate hydrological effects on carbon cycling at the ecosystem scale, which could provide a better understanding of the significant role northern peatland ecosystems play in greenhouse gas cycling at a critical tipping point in our climate.

Preliminary Trade-Offs from the Use of Styrene-Butadiene-Styrene (SBS) Modified Asphalt Binders in Asphalt Mixtures

Student Presenter: Erik Oshaben, Civil Engineering
Faculty Advisor: Amlan Mukherjee, Civil Engineering

Introduction:

The importance of this research has been developed by growing interest to understand the environmental impacts produced by the production of materials. Asphalt is one of the most abundant construction materials in the world which makes the significance of understanding its properties even greater. However, little is achieved by reducing initial environmental impacts if the performance life of the asphalt mixture is shortened. Using trade-off analysis may allow decision makers to confidently choose between the use of different materials and in what quantities in asphalt binders and mixtures.

Materials and Methods:

This project was dependent on life-cycle assessment (LCA). Pertaining to asphalt binders and mixtures, LCA is a process that analyzes background and foreground processes involved in the production of an asphalt binder or mixture. This process allows us to understand the impacts created by not only the asphalt plant, but also production facilities for all materials being used to create an asphalt binder or mixture. For the calculations performed, OpenLCA was used. OpenLCA is a software that allows users to perform LCA calculations with previously created datasets or user gathered data.

Results and Discussion:

Our results found that SBS rubbers showed promising results in terms of an increase in flow number which may be correlated to a reduction of rutting in the asphalt mixture. The determined optimal amount of SBS rubber used in an asphalt binder was 1.55%. Limitations faced included a lack of performance data. The data used was based on laboratory tests and correlates to rutting performance rather that measuring rutting. This data also lacks the presence of variables such climate, underlying pavement structure, and traffic. The data upstream data used to compute global warming potential (GWP) contains proxy data and may not represent the complete scenario.

SURF

Volumetric Segmentation of the Aorta from Cardiac Computed Tomography Scans Using Deep Learning

Student Presenter: Drew Pienta, Mechanical Engineering
Faculty Advisor: Weihua Zhou, College of Computing

Introduction:

The detection and segmentation of the Aorta from a computed tomography (CT) image is a time-consuming task when done manually with the average duration being approximately 30 minutes. This is far too much time when dealing with high mortality conditions such as Aortic Dissection and Malperfusion Syndrome. For this reason, an automated computational method is needed to accelerate the segmentation of the Aorta from CT scans. The primary aim of this project is to develop a computer program that has the ability to ingest full CT scans and return the Aortic volume in voxel form.

Materials and Methods:

The software package 3D Slicer was used to manually generate ground truth segmentations of the Aortic volume from 20 CT scans. The programming language Python was used in conjunction with the Deep Learning libraries TensorFlow and Keras. To accomplish accurate segmentations, a 3D encoder-decoder convolutional neural network known as VNet was developed. All data was downsampled on the transverse plane with random rotations, image sharpness, and contrast adjustments being applied. To account for the severe foreground-background class imbalance, a Dice loss was used during training. Training and validation was run using a leave-one-out testing methodology wherein 19 scans were used for training while the remaining 1 scan was used for validation. Every other scan was validated separately. The validation results were then averaged and the standard deviation taken. Quantitative scoring was achieved using the Sørensen–Dice coefficient with 1.0 being the maximum score possible and 0.0 being the minimum.

Results and Discussion:

The validation average Dice score was 0.94 ± 0.03. This compares with other studies regarding the automatic segmentation of the Aorta using Deep Learning methods. Fantazzini et al. (2020) achieved a Dice score of 0.93 ± 0.02. Bai W. et al. (2018) achieved an average Dice score of 0.957. Gamechi et al. (2019) achieved a score of 0.95 ± 0.01.

The results achieved in this study are consistent with current Aortic segmentation algorithms. This allows for future work to be done that makes use of this automatic segmentation algorithm. Such applications include the automatic detection of Aortic dissection or aneurysm, both of which are time critical and have clinical value to improve the aortic repair or replacement.

Evaporation Rates on Surface of Sessile Droplet on an Incline

Student Presenter: Erik Pitcher, Mechanical Engineering and Applied Computational Mathematics
Faculty Advisor: Hassan Masoud, Complex Fluids and Active Matter Lab

Introduction:

When spilled coffee dries on a surface, the particles contained in the droplet form a ring shape on the surface. This is an example of the coffee ring effect, where fluid within the droplet flows outward radially to the edge. Beyond the domain of drying coffee, a physical understanding of the pattern of particle flow can be beneficial for micro/nano-scale manufacturing and inexpensive medical diagnoses using blood. In order to determine how the fluid flows inside the droplet, we must first derive an analytical solution for evaporation rates over the surface of the droplet.

Materials and Methods:

Continuing off the research conducted by Timm, et al.[1], where the shape of a droplet on a slope was normalized to a spherical cap-shape, we determined an equation for vapor concentration in the volume of space surrounding the droplet. Assuming near steady-state conditions and no convection, the Laplace equation in toroidal coordinates fits this domain and diffusion problem. Applying separation of variables on the Laplace equation, we were able to determine a general form of the solutions[2]. Three boundary values were then applied: zero-flux through the substrate, zero concentration far away from the droplet, and constant concentration on the surface of the droplet. This process was repeated twice for the uninclined (axisymmetric) and the inclined (non-axisymmetric) cases, producing two equations which can be superimposed to form the overall evaporation rates on the surface of the droplet. It is impossible to have exact solutions for two coefficients appearing in the non-axisymmetric equation, so we must use numerical integration to determine more precise values for evaporation.

Results and Discussion:

As far as we have conducted, we currently have two equations for the zeroth- and first-order solutions for the evaporation profile of the sessile droplet on an incline. However, in order to obtain data, the values these equations represent, they must be numerically computed in a program such as MATlab or Python. These simulations will occur over the coming weeks of February, and will provide CFAM with the boundary conditions needed to analytically solve the fluid flow for an evaporating stationary droplet. Understanding the physical theory of evaporation droplets, as mentioned before, will advance many fields, such as fluid mechanics, manufacturing, nanotechnology, and medicine.

[1] M. L. Timm, E. Dehdashti, A. J. Darban, and H. Masoud, “Evaporation of a sessile droplet on a slope,”Scientific reports, vol. 9, no. 1, pp. 1–13,2019
[2] N. Lebedev, Special functions and their applications.

SURF

The Exhumation History of the Bell Creek Batholith

Student Presenter: Emilie Pray, Geology
Faculty Advisor: Chad Deering, Geological and Mining Engineering and Sciences

Introduction:

Our understanding of the geologic history of the Upper Peninsula of Michigan is limited because the rocks range in age from ~2.6 to ~1.0 billion years old and have been modified by multiple plate tectonic events. However, the magma produced throughout this time froze within the Earth and still captures the crustal evolution. The Bell Creek Batholith, a large 'frozen magma reservoir,' contains a number of magma injections that record the progressive exhumation of crust. In this study, we examined the pressure-temperature evolution of these magmas through time to determine changing rates of crustal evolution related to specific tectonic events.

Materials and Methods:

Field observations were recorded while sampling rocks representative of a number of different apparent magmatic injections from exposures alongside Route 95 near Republic, Michigan. The focus was to collect mafic rock samples at exposures where the contacts with the surrounding felsic units could be recorded in detail. These samples were processed in the rock preparation lab at MTU and were subsequently sent to ACTLABS to obtain bulk-rock geochemistry. ACTLABS used x-ray fluorescence (XRF) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) to obtain bulk-rock chemical data for each sample. This data was used to determine geochemical groupings from the samples; each representing a different intrusion event. Representative samples from the determined groups were sent to ACTLABS to collect Sm-Nd isotope chemistry to obtain dates. Thin sections were made in the rock preparation lab and used for petrographic analysis using university microscopes. The thin sections were also used to collect amphibole mineral data using the electron microprobe at the University of Michigan. Geothermobarometric calculations were made using the amphibole chemistry to acquire temperatures and pressures for each group.

Results and Discussion:

The bulk-rock chemistry was used to determine that there are six groups that represent separate magmatic intrusion events through time. We expect that at least a few of these groups will correlate with major tectonic events that occurred between ~2.6 and 1.1 billion years ago, such as the Penokean Orogeny (~1.8 billion years ago) and the Midcontinental Rift (~1.1 billion years ago). The pressures and temperatures calculated from the amphibole geothermobarometry will be plotted with the Sm-Nd dates collected for each group and will be used to calculate associated depths. An exhumation rate for the batholith will be calculated using the depths and ages that were determined for each group. It is expected that the oldest samples will have the greatest depths. Once the exhumation rate is established, the field observations collected will further provide detail to determine the exhumation history for the batholith and its associated magmatic evolution. As the Bell Creek batholith makes up much of the Marquette region, establishing its exhumation history will provide considerable insight to the region's geological history. The preliminary results of this study indicate that the crust has been progressively exhumed from over 12 km to its current exposure over ~1.5 billion years.

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Assessing Intra-Crown Plasticity via Foliar Anatomy of Japanese Beech Across a Latitudinal Gradient

Student Presenter: Rebecca Rooney, Applied Ecology and Environmental Science
Faculty Advisor: Molly Cavaleri, College of Forest Resources and Environmental Science

Introduction:

Phenotypic plasticity is one mechanism by which plants may cope with changing environmental conditions. The ability to readily respond to shifts under a changing climate will be critical for long-lived, slow-migrating species such as Japanese beech (Fagus crenata). Abiotic factors vary across a species' range, which can affect intra-individual plasticity. However, the specific factors that induce high plasticity are not fully understood. Here we examine within-crown variation of leaf anatomy from Japanese beech to assess differences in plasticity both by location and between genetic lineages. We correlate plasticity with environmental factors to assess potential drivers of leaf anatomical variation.

Materials and Methods:

Leaves were collected at five field sites across F. crenata's current range in Japan between 2015-2017 from two distinct genetic lineages of the species. Fully expanded leaves were collected from within each crown using vertical transects from the lower to the upper crown and were categorized into five height classes. Leaves were thin sliced using a freezing microtome and digitally photographed. Anatomical measurements were processed using ImageJ software to measure leaf thickness, palisade cell layer thickness, percent intercellular airspace (IAS), and epidermal cell size.

Intra-crown leaf plasticity was examined using two methods. The first uses linear regressions and ANCOVAs of intra-crown leaf plasticity (ILP), factoring height and canopy openness as covariates. Each trait was evaluated by location to allow for comparison of ILP values, which are represented by the slopes of the regressions. The second method was a plasticity index (PI) to allow for comparison both across traits and without the inclusion of covariates. Linear regressions were used to examine how PI values were related to several environmental factors across the species' range in Japan: mean annual temperature (MAT), mean annual precipitation (MAP), elevation, and latitude.

Results and Discussion:

We found that intra-individual plasticity varied across Japanese beech's range and did not correlate with latitude. Our results suggest that regional environmental factors played a significant role in the development of leaf functional traits and that high plasticity sites were not clearly influenced by a single factor. This is demonstrated by the distribution of high plasticity sites, which follow no clear pattern across the species range. Furthermore, we found no significant differences in levels of plasticity between genetic lineages. When plasticity was correlated to environmental factors, elevation was found to be a stronger driver of intra-individual plasticity than MAP or latitude. We suggest that a mosaic of environmental conditions can induce higher intra-individual plasticity and that inferences about how plasticity manifests across a landscape may not be straightforward. Ultimately, increasing our knowledge of how plasticity manifests over a species range serves in understanding a species' acclimation capacity under climate change.

Collagen V Promotes Cell Contractility and Adhesion Compared to Collagen I

Student Presenter: Shaina Royer, Biomedical Engineering
Faculty Advisor: Sangyoon Han, Biomedical Engineering

Introduction:

Collagen is the primary structural protein in animals. Collagen types I and V are fibrilar types of collagen. Whereas collagen I is substantially more abundant, collagen V plays a regulatory role in the formation of collagen fibers. Cell adhesion on collagen V is under-studied to that on collagen I. One study has shown that fibroblasts cultured on collagen V detach from the substrate and ball up to forming a large clump. In contrast, cells cultured on collagen I show normal spreading and proliferation. I hypothesize that cell adhesion to collagen V increases cellular contractility via strong binding via its integrin-mediated adhesions.

Materials and Methods:

Traction force microscopy (TFM) was used to evaluate the possibility that cell contractility was contributing to the balling up behavior. Silicone gel with a 2kPa elastic modulus was spin-coated onto a glass-bottom tissue culture plate and cured in an oven. Salinization was done with 5% (3-Aminopropyl)triethoxysilane in ethanol. Bead coating was done by sonicating a mixture of 4950µl DI water, 50 uL of 100x 1-Ethyl-3-(3-dimethylaminopropyl)carbodiimide, and 1 µL of 0.04 µm carboxylate coated polystyrene beads for 15 minutes and pouring onto the substrate. Sterilization was done by rinsing in 70% ethanol, then exposing to UV light for 20 minutes. Collagen coating, with either collagen I or collagen V, was done by diluting collagen in PBS to a concentration of 1 µg/mL. 310 uL of EDC was added to 3.1 mL collagen solution, poured onto substrate and incubated for 30 minutes. NIH 3T3 fibroblasts expressing mRuby-paxillin were seeded on the TFM gel dishes 4 hours before imaging. Imaging was done using total internal reflection with a 60x objective. Cells were lysed using bleach to take reference images. Image analysis was done using Matlab-based TFM package and an adhesion analysis function written in Han Lab.

Results and Discussion:

Traction quantification has revealed that NIH 3T3 fibroblasts exhibit greater contractility on collagen V compared to collagen I. Cells cultured on collagen I exhibited traction forces in the range of 10-20 Pa whereas those cultured on collagen V exhibit 100-200 Pa, which is similar to fibroblasts cultured on fibronectin. Adhesion analysis showed that focal adhesions of fibroblasts cultured on collagen I and collagen V are similar in size and shape. However, focal adhesion density was greater in fibroblasts cultured on collagen I. Traction per adhesion increased from nascent adhesions to focal adhesions in both conditions however a greater increase was observed with cells cultured on collagen V. Possible explanations for the difference in contractility observed between cells cultured on collagen V and collagen I are 1) different integrin heterodimers bind to different collagen types, thus triggering differential levels of mechanotransduction response; and 2) the coated collagen I is substantially softer than the collagen V, thereby deforming a lot in the collagen layer rather than in the silicone gel. To test these possibilities, I will interfere with integrin avb3 binding using avb3 blocking antibody and measure local stiffness of the two collagen coating on a glass using atomic force microscopy.

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Accurate Theoretical Prediction of Anharmonic Infrared (IR) Spectra of Neutral Polycyclic Aromatic Hydrocarbons (PAHs)

Student Presenter: Collette Sarver, Chemical Physics
Faculty Advisor: Loredana Valenzano-Slough, Chemistry

Introduction:

The presence of chemically complex molecules such as polycyclic aromatic hydrocarbons (PAHs) in the interstellar medium and in circumstellar environments, has recently elevated the potential for carbon-based Life outside Earth. While IR spectroscopy allows for the indirect observation of PAHs, the complexity and, yet similarities of these molecules make the interpretation of their spectra extremely challenging. For this reason, anharmonic IR spectra can become a powerful interpretative tool of signals collected by probes. The goal of this project is to contribute to the NASA Ames PAH IR spectral database by determining theoretical anharmonic IR spectra of neutral PAHs.

Materials and Methods:

In this project, state-of-the-art electronic structure methods were used to determine and interpret anharmonic IR spectra of neutral PAHs. The Gaussian 16 electronic structure program was used to perform quantum chemical calculations at various levels of theory to provide the scientific community with more up-to-date indications about the best theoretical approaches to use for future investigations. Density functional theory (DFT) approximations (B3LYP) were employed in combination with two atomic localized basis sets, 4-31G and 6-31G. Additionally, calculations were performed without symmetry (i.e., C1 point group) and at the highest symmetry available (for example, C2v). Each molecule was first relaxed at the various levels of theory to find its equilibrium geometry. Harmonic and anharmonic IR spectra were then determined and compared to the currently calculated and experimental spectra available at the NASA Ames IR PAH Spectral Database, and in the more general literature.

Results and Discussion:

After geometry relaxation, harmonic and anharmonic IR spectra were determined. Analysis of the results includes an assessment of the impact of molecular symmetry on the spectra, and a comparison with available experimental data. Species investigated include bicyclo[4.2.0]octa-1(6),2,4-triene, styrene, ethylbenzene, and indene. Overall, the most intense harmonic and anharmonic bands for PAHs are found either in the 700-800 cm-1 (CH bending) or the 3000 cm-1 range (CH stretching). Additional anharmonic vibrational modes appear in the IR spectra due to combination and overtone modes, showing the importance of determining PAHs' IR spectra beyond the harmonic approximation. It is worth mentioning that some anharmonic calculations conducted at the B3LYP/4-31G level failed due to the poor electron density generated by such a minimal basis set. This last comment is of actual practical importance since the vast majority of the astrophysical/astrochemical community still refers to B3LYP/4-31G results and are limited to harmonic spectra. It is expected that the original results obtained in this project will provide a solid proof for the necessity of higher standards for the determination of more accurate theoretical spectroscopic data which will be used to compare, analyze, and interpret spectra collected by the James Webb Telescope, scheduled for launch in 2021.

Analyzing the Hydrophobicity of Viruses: A Comparison of Adsorption Isotherms and Chromatography

Student Presenter: Ellie Sempek, Biochemistry and Molecular Biology
Faculty Advisor: Caryn Heldt, Chemical Engineering

Introduction:

The surface chemistry of a virus will determine where it will stick or how it can be purified. The virus charge is easy to measure, but surface hydrophobicity is much more difficult to measure. Yet, hydrophobicity is what will determine if the virus will stick to a vial that contains a viral vaccine. This work examined the hydrophobicity of viruses in a comparison of chemical force microscopy and adsorption isotherm in order to find a way to measure virus hydrophobicity and to optimize the virus purification process.

Materials and Methods:

Virus hydrophobicity is being measured by the adsorption of virus to hydrophobic phenyl and butyl Sepharose chromatography resins. The virus, porcine parvovirus (PPV), was diluted in 1X PBS (155mM NaCl) and adsorbed to the chromatography resins at different concentrations. It is extremely important that the amount of beads and the amount of virus added be the same in each experiment. The virus solution and beads were thoroughly mixed in order to fully incorporate the virus into the resins. This ensures that PPV has the highest adsorption possible. After 90 mins, the supernatant is extracted and measured for infectious virus by the MTT Assay. The MTT Assay uses PK-13 cells to measure the concentration of virus left unabsorbed after they have been mixed with the beads. To increase the amount of virus that would bind to the beads, the salt concentration was increased to 1X PBS with 350 mM NaCl. Increased virus starting concentrations were used. The goal is to develop a Langmuir isotherm model of viral binding to hydrophobic beads. The binding of different viruses will be compared to chemical force microscopy.

Results and Discussion:

This research is ongoing. Currently, the data of the experiment shows inconsistencies between the final virus concentration in the three runs for each separate starting virus concentration. These inconsistencies affect the final average virus concentration used in analyzing the results to determine resin selection. Method improvement and multiple runs will be necessary to acquire more reliable data before moving forward. The findings of this study will help in the understanding of virus hydrophobicity, to compare to the new chemical force microscopy method to measure virus hydrophobicity, and improve our knowledge on how virus hydrophobicity affects the purification process.

Presence of Spotted-Wing Drosophila in Wild Berry Species of Great-Lakes Region

Student Presenter: Alexis Shatrau, Biochemistry and Molecular Biology
Faculty Advisor: Erika Hersch-Green, Biological Sciences

Introduction:

Spotted-Wing Drosophila (SWD) is an invasive fruit fly that was first reported in Michigan in 2010 (1). SWD targets soft mass fruits, ovipositing its eggs through the fruit surface, and causing premature fruit fall or rotting; all of which could negatively impact human and wildlife species that depend upon these fruits. While much is known about SWD in agricultural plots we know little about SWD in wild berry populations. In this study, we collected data from 2019 and 2020 on percent infestation of SWD larvae in wild berry species in the Northwest Upper Peninsula MI.

Materials and Methods:

Between July and September 2019 and 2021, we collected soft-fruit wild berries in the Huron Mountains (roughly weekly) and Keweenaw Peninsula (differing frequencies). At each site, ripe berries were collected, berry species identified, transported to the lab in a cooler, and berries counted; the number of berries ranged from 50-300 per site per collection period and depended upon availability.

In the laboratory, SWD presence/ absence and average larval counts were determined with a simple salt extraction method (1 cup of iodized salt per 1 gallon of warm water was combined) and a microscope. Briefly, berries in the bags were lightly crushed between fingers, the salt solution was poured into the plastic bags, and bags with berries and solution were maintained at room temperature for 1-2 hours. Next, bagged contents were filtered and the presence and number of larvae per bag were determined. Statistical analysis was done using JMP software.

Results and Discussion:

Overall we collected 39,100 berries over the two years from 6 different genus and 4 different plant families including Caprifoliaceae (raspberry, thimbleberry), Ericacea (blueberry, huckleberry), and Rosaceae (honeysuckle, snowberry) and Prunacea (cherry). In both years the averaged #SWD/Fruit collected generally increased as the collection season progressed but it depended upon berry species.

In the early season of both years, there was almost no infection present in Rosaceae, Ericacea, and Caprifoliaceae families. In the middle season, the following data was collected: Rosceae had .2 SWD/berry in 2019 and .6 SWD/berry in 2020, Ericacea had ~0 SWD/berry in 2019 and 2020, and Caprifoliaceae had .2 SWD/berry in 2019 and .1 SWD/berry in 2020. In the late season, there was the highest infectious rates; Rosaceae had 1.4 SWD/berry in 2019, and 1 SWD/berry collected in 2020, Ericacea showed .4 SWD/berry in 2019 and .1 in SWD/berry in 2020, and finally Caprifoliaceae showed 0 SWD/berry in 2019 and .2 SWD/berry in 2020. With this data further research could be explored on the optimal timing of preventative measures to combat the high SWD infestation rates particularly in the late season.

SURF

Optimization of Lignin Precipitation with Functional Group Control for Use in Bio-Based Polyurethane Foams

Student Presenter: Lauren Spahn, Chemical Engineering
Faculty Advisor: Rebecca Ong, Chemical Engineering

Introduction:

Lignin, an organic polymer, can be precipitated from black liquor, a byproduct of the pulp and paper industry. Lignin has the potential to replace petroleum-derived polymers in many applications, such as polyurethanes. In this project, lignin is demethylated during the precipitation process. This makes use of high pH conditions early in the process and is intended to increase the proportion of hydroxyl groups, thereby increasing lignin reactivity and integration into the polyurethane network. Using previously optimized precipitation conditions of a modified Ligno-Boost procedure, the resulting demethylated lignin can be used to create a broad range of sturdy bio foams.

Materials and Methods:

The catalyst dodecanethiol was used for the demethylation because it operates under alkaline conditions, greatly simplifying the process by completing demethylation before acidification during precipitation. An experimental plan for the optimization of dodecanethiol was created in order to analyze the effect of different concentrations on the amount of hydroxyl groups in the resulting lignin. A factorial design of experiments was implemented using 5 wt % dodecanethiol at 15 and 30 minute residence times at the beginning of lignin precipitation. Previously optimized lignin precipitation conditions of CO2 residence time of 1.5 hours, 85 °C for acidification with H2SO4 and final pH of 1.7 were retained in this project.

The lignin product will act as a polyol and react with an isocyanate in the formation of bio foams. The isocyanate chosen was polymethylene polyphenyl isocyanate, and glycerol propoxylate was chosen as a synthetic polyol. The resulting foams will be tested for performance in properties such as flexibility, tensile strength, and impact resistance compared to a control foam created in the lab. Lignin-based foams will be compared to the control foam in order to determine how much lignin can be added while maintaining the mechanical properties of petroleum-based polyurethane foams.

Results and Discussion:

The calculated solid mass yield across each experiment was found to be relatively similar compared to the control experiments. From this, we can conclude that this method of lignin precipitation is repeatable and reliable. It is also important to note that neither the addition of the thiol, nor the thiol residence time, appear to have any significant effect on the solid mass yield, which means that lignin demethylation can be achieved without significant loss in lignin yield.

Current work for this project involves using 31P-NMR and FTIR to analyze the hydroxyl content of the final lignin product. If it can be determined that the demethylation was successful and there are significantly more hydroxyl groups present in the lignin molecule, the generation of lignin-polyurethane foam samples can proceed. Increased lignin hydroxyl content is expected to result in more rigid foams due to the increased capacity for crosslinking as well as darker coloration due to the presence of lignin. These tests will show how these lignin-based foams can act similarly or even better than existing products in industry such as cushions, packaging, furniture, and fiber applications.

Nocturnal Stomatal Conductance of Carex Oligosperma

Student Presenter: Lukasz Spiewla, Natural Resources Management
Faculty Advisor: Erik Lilleskov, USFS Northern Research Station

Introduction:

There is limited oxidation and decomposition of organic matter in peatlands due to high water tables limiting aerobic processes from occurring. To counteract the high-water stress, Carex oligosperma have adapted aerenchyma, which supply oxygen to submerged roots by creating a direct pathway for gas exchange from stomata to the roots. Evidence suggests that rhizosphere microbes capitalize from this steady supply of oxygen to perform aerobic metabolism around aerenchyma. Some plant species living under flooded conditions have been observed to leave stomata open through the night, presumably to maintain root oxygenation and prevent hypoxia.

Materials and Methods:

The conditions of the USFS Treepeat experiment created a good experimental model for my project. I had access to 12 populations of established Carex oligosperma divided between 6 high and 6 low water table treatments. Using a Licor-6400, I captured variables of conductance logged against humidity, temperature gradient, and vapor pressure deficit to determining stomatal openness. Live sedges, in groups of 3 stalks, were measured by diameter and marked in bins prior to measurements. To supplement the data collected from midday and midnight measurements, light response curves were also measured alongside midday measurements. Photosynthetically Active Radiation was measured on a stalk bundle with each daylight measurement at 9 different levels of PAR ranging from 1500 to 0. In order to further investigate the conductance of Carex oligosperma, Abscisic acid was used to induce stomatal closure in plants both in day and night. By using ABA, a minimal stomatal conductance value was able to be determined for the Carex oligosperma tested. 3 Stalks were excised and placed into 2 vials of either DI water or ABA solution for each bin sampled, stalks placed in ABA solution quickly saw changes to conductance within an hour of being placed in solution.

Results and Discussion:

Stomatal conductance is greatest in unimpeded daylight measurements. This is followed closely by excised stems placed immediately in DI, only having slightly lower rates than the daylight measurement. At low light levels of less than 50 PAR, conductance drops to about 50% that of full daylight and DI. Nighttime conductance is significantly lower than light-present treatments, at about 25% conductance compared to light-present treatments. ABA conductance was found to be even lower than nighttime conductance, at about 50% that of nighttime conductance. None of the values had a conductance rate of zero. In a comparison to a review of minimum conductance, stomatal conductance of Carex oligosperma was greater than the mean of all estimates from the review, in most cases, higher than one standard deviation. The stomata of Carex oligosperma are neither fully open, nor fully closed at night. Carex oligosperma also displays a higher-than-average stomatal openness than other species at nighttime. Carex oligosperma also does not exhibit significant difference in stomatal regulation due to differences in water table depth.

The Daily Spaces and Environmental Hazards for Youth in the Industrial City

Student Presenter: Timothy Stone, Sustainability Sciences and Society
Faculty Advisor: Don Lafreniere, Social Sciences

Introduction:

The built and social environments in which children lived in industrial cities in 20th century America is a valuable yet largely underrepresented area of study. The study of the historic industrial city can provide remarkable insight into child-city dynamics with contemporary implications such as fighting the childhood obesity epidemic, generally improving children's standard of living, and better-informing the creation of policies that will impact children. In addition, study of this type will provide insights into how children were impacted by environmental factors that have traditionally been studied in adults, such as proximity to noxious land uses and crowding.

Materials and Methods:

To do this, we utilize the Copper Country Historical Spatial Data Infrastructure (or CCHSDI), which is a spatial-temporally linked historical geographic information system built on period-accurate Sanborn Fire Insurance Plans (FIPS). The CCHSDI links built, social, and environmental variables across seven decades from 1880-1950, with our focus being in the towns of Calumet and Laurium in Michigan's Upper Peninsula. On the individual scale, the CCHSDI links Polk City Directories, IPUMS full-count census data, mining company employee records, and school records from the local public schools across space and time. These school records provide the basis for this project, spanning from 1904-1926. Using projections from the World Bank's Industrial Pollution Projection System, we created a time-weighted estimated risk variable to illustrate differences in pollution exposure throughout both towns. This risk variable illustrates the experiences of children with the built environment, relative to one another, in terms of proximity to buildings noxious uses (e.g. mining operations, factories, railway lines). We build on previous historical work by examining the separate activity spaces of each child (home, school, and commute) rather than solely at home.

Results and Discussion:

Preliminary results show increased health risk associated as children spent more time near noxious land uses. In addition, other built environment factors, such as residential crowding and recent immigration, may increase health risk.

Recent developments in fields such as Childhood Environmental Health have demonstrated the importance of a child's built and social environments on their life-course health. By examining the quality of the built environment in each activity space, we are able to apply a similar methodology to that used in contemporary studies, providing a more complete picture of each child's day. Thus, our analyses of the built and social environments and their impacts on children can mirror the comprehensiveness of contemporary studies (whereas historical studies are typically limited to exposures at home), while also maintain the individual-level scale of historical studies (whereas contemporary studies are typically limited to aggregate scales such as zip codes, census tracts, or counties). This provides greater analytical certainty when examining relationships between the built environment and measurable life-course health outcomes, such as absences from school, perceptivity to disease transmission, and, in some cases, cause of death.

Impacts of Mesh Size & Surface Hydrophobicity on Flooded-Bed Scrubber Clogging

Student Presenter: John Szczap, Chemical Engineering
Faculty Advisor: Lei Pan, Chemical Engineering

Introduction:

There has been a recent uptake in cases of progressive massive fibrosis (PMF) among coal miners. Flooded-bed scrubbers are commonly used to collect coal mine dust particles by drawing particles-loaded air through a metal mesh with water mists sprayed. However, filters clog over time causing dust to flare and operations to cease. I have been leading a project to study the clogging of filters by determining the impact of different operational variables and mesh configurations on filter clogging. It has been shown that both mesh size and surface hydrophobicity impact the accumulation/rate of clogging. By the end of this project, the data will provide insight into filter optimization and increased safety for coal miners.

Materials and Methods:

An experimental apparatus was constructed that uses differential pressure readings and a hotwire anometer to study a simulated flooded bed scrubber filter.

Results and Discussion:

The study has shown that both mesh size and filter materials contact angle do have an impact on filter clogging

Experimental Characterization of Photo-Sensitive Polymers to Optimize UV Usage Parameters

Student Presenter: Joseph Van Linn, Mechanical Engineering
Faculty Advisor: Trisha Sain, Mechanical Engineering

Introduction:

This research describes the current experimental work and corresponding theory to characterize the light and heat absorption surface localization effects during stereolithographic curing processes. Stereolithographic curing is a common practice of additive manufacturing utilized to prototype and manufacture complex geometries in a short time frame and at low cost via the crosslinking of liquid monomers under the exposure of UV radiation. Radiative energy transfer is the primary energy source to initiate crosslinking. The propagating UV light reflects during the curing process which creates an uneven radiative energy transfer in the sample and in turn a variation of mechanical properties of the final cured product.

Materials and Methods:

Polydimethylsiloxane (PDMS) is a viscoelastic polymer that with the addition of xylene and benzophenone becomes susceptible to radiative energy. This polymer is cured in the MEEM department via UV exposure followed by thermal treatment. The preliminary experiment utilizes tensile testing and dynamic mechanical analysis (DMA) of the elastomer to identify the surface localization severity and its effects on mechanical behavior.

Results and Discussion:

The initial achievement of the work is the ability for the MEEM department to now cure their own polymer susceptible to UV radiation and quantify its properties via tensile testing and DMA. A significant challenge this year was identifying a tensile geometry that will fracture in the gauge via trial and error. With this identified, testing moved to DMA to quantify the viscoelastic properties of the material. The next step of the project is using DMA to quantify the changes in the mechanical properties of photo-sensitive PDMS as independent variables are changed.

DeVlieg Foundation

Non-invasive Breath Analysis for Testing Blood Glucose Levels in Diabetics

Student Presenter: Noah Wilson, Physics
Faculty Advisor: Jacek Borysow, Physics

Introduction:

Type 1 Diabetes is a fairly common disease that affects around 40,000 new people annually in the US. The average age of onset is ~14 years old and this disease will stay with them for their entire lives. The most common way to test one's blood glucose is by finger prick and the average diabetic will end up doing this ~250,000 times in their lifetime. The objective of this research is to determine whether there is a correlation between acetone concentration and blood glucose (BG) by using Raman spectroscopy and breath analysis.

Materials and Methods:

Breath samples from the subject were placed in a breath container. This was repeated multiple times to achieve a satisfactory Raman spectrum. The levels of nitrogen were measured as a reference for the acetone levels because the body does not use or produce nitrogen, thus it remains constant. Within the same time frame that the acetone measurements are being taken, the subject tested their BG multiple times on their glucose meter as well as recording the reading of their continuous glucose monitor. This will allow for the most accurate representation of their blood glucose at the time of the breath sampling. It takes approximately 30-60 minutes to measure the acetone levels but use the same breath sample. Samples were analyzed by this method for a large range of blood glucose levels (70-300 mg/dL) to obtain a large enough sampling to confidently understand what the spectrographs and glucose levels are showing. We then analyzed any data containing acetone from the spectrometer and the subject's blood glucose to see if there is a correlation between acetone concentration in one's breath and their blood glucose.

Results and Discussion:

Breath samples from the subject were placed in a breath container. This was repeated multiple times to achieve a satisfactory Raman spectrum. The levels of nitrogen were measured as a reference for the acetone levels because the body does not use or produce nitrogen, thus it remains constant. Within the same time frame that the acetone measurements are being taken, the subject tested their BG multiple times on their glucose meter as well as recording the reading of their continuous glucose monitor. This will allow for the most accurate representation of their blood glucose at the time of the breath sampling. It takes approximately 30-60 minutes to measure the acetone levels but use the same breath sample. Samples were analyzed by this method for a large range of blood glucose levels (70-300 mg/dL) to obtain a large enough sampling to confidently understand what the spectrographs and glucose levels are showing. We then analyzed any data containing acetone from the spectrometer and the subject's blood glucose to see if there is a correlation between acetone concentration in one's breath and their blood glucose.

Electrophysiological Correlates of Visuomotor Adaption

Student Presenter: Emily Wisz, Psychology
Faculty Advisor: Kevin Trewartha, Cognitive and Learning Sciences

Introduction:

Motor learning is a specific type of learning that occurs through repetition of a movement. While the neural mechanisms associated with age-related changes in early motor learning are not fully understood, previous research suggests that there are reductions in motor learning tasks in later adulthood. The primary purpose of this study is to advance our understanding of the neurocognitive mechanisms involved in the acquisition of a new motor skill through the use of electroencephalogram (EEG) data. A secondary goal of this study is to better understand how aging affects the neurophysiological and cognitive basis of motor learning.

Materials and Methods:

This project aims to recruit roughly 25 healthy younger adults to compare to a recently collected sample of healthy older adults. Motor learning will be investigated by having participants reach to visual targets while grasping a handle attached to a robotic device (KINARM). Participants will be asked to move the cursor representing their hand from a starting location to a target location. Initial learning trials involve the cursor moving congruently with the participant's movement of the handle. In subsequent trials, the cursor will be offset 45° clockwise or counterclockwise from the participant's movement of the handle. The goal of the task is still to have the cursor reach the target location. Learning curves will be acquired to determine how quickly participants learn to compensate for the visual shift. Participants will also undergo four cognitive tasks: spatial paired-associate learning (working memory), Stroop task (executive functioning), flanker task (executive functioning), and n-back task (working memory). While participants perform the n-back and motor learning tasks, continuous EEG recordings will be obtained using an active electrode EEG system. Data epochs will be created around stimulus events to assess the amplitude and latency of an event-related potential component.

Results and Discussion:

As this study is still ongoing due to delays related to COVID-19, we do not have any preliminary results to report at this time.

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What Are the Best Practices to Integrate Therapy Gardens into Programs Servings At-Risk Populations?

Student Presenter: Alannah Woodring, Sustainability Science & Society
Faculty Advisor: Angie Carter, Social Science

Introduction:

Every year in Michigan 103,330 women are affected by domestic violence and some of them are seeking women's shelters that provide temporary shelter and counseling services for residents. One method of healing from trauma comes from therapeutic gardens. Therapeutic gardens are places where women can regain mindfulness after a triggering event leading to healing from trauma. The Barbara Gundlach Shelter Home in Calumet, MI was working with a group of researchers, planners, and public health directors to build therapeutic gardens for their residents. This research studies the best ways to integrate therapeutic gardens within existing programs to ensure they have a successful program.

Materials and Methods:

The research began with an extensive literature review studying therapeutic gardens and trauma-informed healing. Next was researching individuals who had expertise in therapy gardens in Michigan and reaching out to them for an interview. After having a difficult time reaching my interview goal of 5 people, I began to research in Wisconsin and Ohio for interviewees in hopes of finding more people to reach out to. Once I received some responses, I performed hour-long semi-structured interviews over Zoom, which were recorded. I then transcribed the interviews and began coding in NVIVO, a qualitative data analysis software. I used grounded theory when coding, identifying main themes along with important topics.

Results and Discussion:

During my interviews, I was told about best practices to ensure a beginning program was successful and sustainable for years to come. From the interviews, some of the main takeaways were creating an inviting and calming atmosphere, plants that are inclusive to multiple senses, and creating lifelong community connections to ensure there is always help within the garden upkeep. There needs to be a calming atmosphere created by soft feeling plants, bright-colored plants, and visual decor. From my research, I was able to create a list of plants taking into consideration sensory effects. This list has photos of each plant, best season, and general information about growing requirements. Another key aspect is ensuring that after the initial excitement from the research group, there is always someone to help with maintenance such as spring and fall upkeep. The garden space invites crosstalk of “how are you getting the weeds out of your life?” when performing maintenance. Overall, the goal is to create multiple opportunities for women to get involved and create a space where they can feel empowered.

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Fibrin-Based Materials for the Modulation of Matrix Metalloproteinases in Tendon Repair

Student Presenter: Jordan Zais, Biomedical Engineering
Faculty Advisor: Rupak Rajachar, Biomedical Engineering

Introduction:

In tendon injury repair, no current therapies aim to restore the extracellular matrix (ECM) structure-function balance. Our lab has developed injectable, adhesive PEG-fibrinogen hydrogels that incorporate S-Nitroso-N-acetyl-Penicillamine (SNAP)-fibrin microparticles with the goal of aiding in soft tissue wound repair through the therapeutic exogenous delivery of nitric oxide (NO), which is known to influence ECM modulation through regulation of matrix metalloproteases (MMPs). MMP activity is also known to be affected by fibrin. In a recent study, our lab observed that the fibrin-degradation products (FDPs) from the microparticles can significantly regulate MMP activation and to modulate ECM during tendon healing.

Materials and Methods:

Following a previously established protocol, fibrin microparticles were synthesized by injecting a fibrinogen solution into an oil emulsion and adding thrombin to crosslink the particles. The structure of the particles was changed in one of two ways: 1) adding double the amount of thrombin during particle synthesis or 2) post-synthesis cross-linking using genipin, a plant-based crosslinker. The swelling ratios of these different particles were characterized by measuring the dehydrated and hydrated areas using an EVOS microscope then calculating the swelling ratio (Q=wet area/dry area). The degradation of these particles was also characterized by placing particles into a plasmin solution and assessing over the course of 28 days. The FDPs from this process were then isolated and quantified using a BCA assay. Degradation of standard fibrin-only microparticles served as control for all experiments.

Results and Discussion:

Both the genipin-crosslinked and double-thrombin microparticles showed statistically significant differences in their swelling ratios when compared to the original fibrin microparticles, with both swelling ratios being lower than the fibrin-only particles. The degradation studies are on-going at this time, but we hypothesize that the lower swelling ratio particles will have slower dissolution rates. This research will be continued in the future to analyze the effect of FDPs on MMP activation by culturing the different microparticles with human tenocytes and running western blotting and gelatin zymography.

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