



NJIT



**2026**

**DANA KNOX STUDENT RESEARCH SHOWCASE  
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## #101 | THE COLLECTIVE IMAGE OF THE CITY: URBAN FORM AND SPATIAL PERCEPTION IN NEW JERSEY

This dissertation revisits Kevin Lynch's *The Image of the City* (1960) by returning to Jersey City, one of Lynch's original case studies, to examine how digital mediation, changing settlement patterns and regional growth and fragmentation reshape urban imageability in an expanded urban field. While Lynch foregrounded pedestrian perception of physical form as the basis of urban legibility, this study will investigate how contemporary urban experience unfolds through hybrid navigation across physical, social, and digital layers. Today, platforms like Google Maps, Instagram, and real estate applications shape wayfinding and perception as profoundly as streets, buildings, or signage.

By extending Lynch's wayfinding typologies of paths, edges, districts, nodes, and landmarks to account for digitally mediated perception and social belonging, this dissertation will propose an urban vocabulary for the twenty-first century, one that may include elements such as thresholds, corridors, and anchors that bridge the built, social, and digital realms. This dissertation will theorize these elements not as fixed morphological categories but as dynamic, lived interfaces that reflect evolving patterns of mobility, perception, and identity. Whether Lynch's original taxonomy requires supplementation or fundamental reconceptualization is itself a question this research hopes to answer.

Methodologically, the project combines archival research, spatial morphology mapping, participatory cognitive mapping, ethnographic observation, and digital platform analysis. Building on Lynch's inductive method, this dissertation will propose an "Image of the City 2.0" theorizing the hybrid navigator as a third urban actor alongside the pedestrian and the motorist. By positioning New Jersey as both case and lens, this study seeks to offer a historically grounded and methodologically innovative model for studying perception in fragmented, polycentric, and digitally influenced urban regions.

 Student Researcher: Mansi Shah, Doctoral

 Faculty Advisor: Gabrielle Esperdy

 Architecture, Art and Design

## #102 | THE INTERSECTION OF ICONS: THE CULTURAL DYNAMICS OF STREET ART AND SHRINES IN ROME'S URBAN LANDSCAPE

As a prosperous urban environment, Rome is home to an active street art scene, a contemporary juxtaposition to the historic street shrines of the city. These two artistic counterparts, separated by aesthetic and age, intersect at the cultural and spiritual landscape of Rome's people. Street shrines, embedded in Roman religious history, are landmarks originally used for the Catholic practice of devotion. Street art, as a visual commentary on politics, religion, and personal experiences, has gained prominence as both a sanctioned activity as well as an illicit form of expression. An analysis of spatial and symbolic aspects of the shrines and monumental art reveals how physical proximity, stylistic differences, and theme are influenced by – and influence – Rome's resident population. The role of these installations in shaping the identity of the city affects how both local residents and visitors perceive these spaces of devotion and artistic rebellion. Examinations via the lenses of contemporary Italian history, liturgical art history, and geospatial connections reveal that these two distinct art forms affect each other and people who experience them within the urban fabric, offering insight into the cultural dynamics of Rome's streets. Rome's tradition of vernacular street shrines and contemporary street art, though distinct in origin and intention, operate as interconnected public visual languages whose iconographic, spatial, and chronological interplay reveals how Romans of the past and present continue to form cultural identity and construct shared meaning within the city's changing, layered urban landscape.

 Student Researcher: Emma Fernandes-Santinho, Undergraduate

 Faculty Advisor: Louis Hamilton

 Architecture, Art and Design



## #103 | FLOW INITIATIVE NEXT-GENERATION MENSTRUAL EQUITY VENDING CONCEPT

This Independent Study, in partnership with The Flow Initiative, investigates the design of a next-generation free vending system to improve access to menstrual products in public spaces while integrating AI-supported health education. Limited availability of free products and stigma surrounding menstruation continue to create barriers to health, participation, and dignity, particularly for students, low-income populations, and individuals managing menstruation in shared environments. This project addresses these gaps through the development of a reliable, accessible, and educational public vending concept. The proposed design will include two coordinated units: a full-size machine for installation outside restrooms and a compact version for interior bathroom use. Both dispense multiple absorbency types and sizes of pads, tampons, and liners, along with supplementary care items such as wipes, disposal bags, and stain-removal tools. The system incorporates mechanical dispensing, live inventory monitoring, and misuse mitigation strategies to ensure reliability and continuous access. A key component of the concept is the eventual integration of a digital interface that provides optional, discreet access to menstruation education, product guidance, and health information. Companion mobile app wireframes extend learning beyond the machine, supporting ongoing engagement with curated resources. Through research, iterative design, and concept development, this project demonstrates how inclusive industrial design and digital integration can expand menstrual equity, reduce stigma, and create more supportive public health infrastructure.

 **Student Researchers:** Leah-Marie Boake, Shalaka Ajwalia, Natalia Albarracin Mora, Undergraduate  
 **Faculty Advisor:** Hannah Berkin-Harper  
 **Architecture, Art and Design**


## #104 | URBAN DESIGN STRATEGIES FOR REVITALIZATION OF SHRINKING CITIES

Global cities are experiencing demographic shifts from their centers to the urban periphery. According to the World Bank, Latin America has especially faced the challenges of suburbanization. Emblematic of this trend are the urban changes occurring in Quito, Ecuador where its central historic neighborhood of Mariscal has experienced a dramatic loss in population that has threatened its historic buildings, local businesses, and safety. This research project sought to identify urban design tools and strategies that could contribute to the reversal of this harmful demographic shift.

As a collaboration between NJIT, Universidad SF Quito (USFQ) and local stakeholders, a comprehensive analysis was undertaken for the revitalization of Mariscal. Combining both quantitative and qualitative data, a series of maps and models were created to identify gaps and highlight opportunities for future investments in green infrastructure, mobility, housing, open space, historic and cultural preservation, and strategic economic development.

Data was collected using global information systems (ArcGISPro) from municipal organizations and was cross referenced with historical maps. Google earth satellite imagery was used to model and produce a 3d printed model. Local newspapers and key neighborhood stakeholders were consulted to develop a qualitative understanding of community priorities and current work to address challenges.

The team created a series of thematic overlays to envision a long-term plan of municipal investment along with a series of short-term implementable projects. The maps and models have been presented and made available to local stakeholders to advocate for future investments.

 **Student Researchers:** Carolyn Abdalla, Raunak Tasnim, Sudiksha Sahu, Undergraduate  
 **Faculty Advisor:** Georgeen Theodore  
 **Architecture, Art and Design**






## #201 | WHY GRANDPA DOESN'T TRUST THE DRIVERLESS CAR: A THEMATIC ANALYSIS OF OLDER ADULTS' (DIS)TRUST IN TECHNOLOGY

Older adults consistently distrust, avoid, and abandon the technologies designed to support them. A password manager is rejected because any digital system “could be hacked.” Online banking is avoided because personal data cannot be traced. A health wearable is distrusted because no one explained what it does with a heart rate reading. By 2050, over 1.6 billion people worldwide will be 65 or older. Autonomous vehicles, AI health assistants, and smart home systems are becoming standard infrastructure. Every one of us will eventually age into a world of technology. If that technology was never designed to earn trust, we all inherit the problem.

We analyzed empirical data collected across existing research, such as interviews, surveys, focus groups, and user studies, in which older adults reported their experiences with technology. Our analysis identifies several interconnected themes that structure (dis)trust: privacy concerns, system reliability and design quality, accumulated experience and knowledge, social ecosystems that mediate trust through family and institutions, the invisible labor older adults perform to protect themselves from technology, personal identity and values, and downstream consequences, including avoidance and strategic non-use.

A major finding is that distrust is not a deficit in older adults. It is a rational response to design failures. The patterns this research surfaces are not problems unique to aging; they are problems that aging first makes visible. Solving them now by including older adults in the design process will help us build trustworthy technology for everyone.




-  Student Researcher: Muhid Hassan Risvy, Doctoral
-  Faculty Advisor: Alisha Pradhan
-  Artificial Intelligence, Machine Intelligence & Robotics

## #202 | INTERPRETABLE NEURAL SPEECH-DRIVEN 3D FACIAL ANIMATION: CONTROL AND COARTICULATION

Speech-driven 3D facial animation is increasingly used to create expressive, synchronized digital human performances and is also central to emerging communication and avatar-based interfaces. However, many current systems behave like black-box generators: they produce a single fused performance with limited interpretable control at phonetic detail. This dissertation addresses that limitation by designing structured latent spaces for facial motion—Neural Articulation Space and Neural Visual Prosody Space—where specific control directions correspond to interpretable edits (e.g., articulation strength versus expressive intensity), enabling localized changes without globally rewriting an animation.

The research develops three complementary components. First, a controllable audio-to-motion pipeline factorizes phoneme content and prosody into separate conditioning channels and maps them to latent motion trajectories, supporting targeted edits while preserving synchronization and naturalness. Second, an evaluation framework for controllability measures edit responsiveness and temporal stability in addition to reconstruction accuracy, and examines failure modes such as control saturation where model priors overpower user intent. Third, coarticulation geometry is analyzed by representing facial motion as time-normalized trajectories in latent shape space and testing phonetic context effects via vowel–vowel versus vowel–consonant–vowel comparisons.

Together, these contributions connect production-oriented editability with quantitative analysis of how phonetic context shapes 3D facial trajectories. The expected impact is a more usable class of facial animation models for film and game production workflows and a more interpretable set of tools for studying speech-related structure in learned facial dynamics, with downstream potential for personalized, accessibility-oriented, and interactive avatar interfaces.

-  Student Researcher: Danzel Serrano, Doctoral
-  Faculty Advisor: Przemyslaw Musialski
-  Artificial Intelligence, Machine Intelligence & Robotics






## #203 | REASONING-GUIDED AND STRUCTURED APPROACHES FOR COMPLEX IMAGE EDITING

Modern AI image editing systems can generate highly realistic images in seconds. However, they often struggle when given complex instructions that involve multiple objects, spatial relationships, or step-by-step modifications. As AI-edited images become widely used in media, marketing, and digital content creation, reliability and control are increasingly important. This research aims to design a structured editing framework to improve reliability of the AI image editors.




In this study, a structured image editing framework is designed and systematically tested to improve how AI systems handle complex instructions. Rather than relying on a single global prompt, editing tasks are decomposed into region-level steps, allowing the model to selectively modify specific areas while preserving others. Through the integration of controlled attention mechanisms and iterative refinement strategies, unintended changes are minimized and compositional consistency is strengthened. The framework is evaluated under multi-object editing scenarios, with performance compared against standard diffusion-based editing methods.

The goal of this research is to make AI image editing more reliable, interpretable, and aligned with user intent. By improving structural control during the editing process, this work helps build image editing systems that users can trust in real-world applications. Ultimately, this research contributes to safer and more dependable AI-generated visual content.

-  **Student Researcher: Naidan Zhang, Doctoral**
-  **Faculty Advisor: Frank Shih**
-  **Artificial Intelligence, Machine Intelligence & Robotics**

## #204 | CHARACTERIZING LEARNING AND UNLEARNING THROUGH NEURAL COLLAPSE

Neural Collapse is a recent phenomenon that helps identify sparse and low rank structures in deep classifiers and was initially identified at the final layer of the deep classifiers. Recent studies have extended the scope of neural collapse beyond the classification problem and last layer, naming it as deep neural collapse. To extend deep neural collapse to the regression problem, in the first part of this work, we identify Deep Neural Regression Collapse and its conditions in intermediate layers. In addition, we also show the parallelism between neural collapse in regression and classification models. After defining the deep neural collapse conditions on the regression problem, we turn our focus to machine unlearning (MU), a recent field that focuses on erasing certain data from machine learning models. Machine unlearning has yet to be completely explained, so we utilize neural collapse to explain how MU methods work. In the second part, we conduct an analysis through neural collapse measurements on MU methods and discover a misalignment between last-layer features and the classifier caused by the unlearning methods, which causes MU methods to appear successful, while the hidden features remain highly discriminative, and simple linear probing can recover near-original accuracy. Additionally, we further demonstrate that adjusting only the classifier can achieve negligible forget accuracy while preserving retain accuracy, and we corroborate this with experiments using classifier-only fine-tuning, assuming that the original model has collapsed. Finally, we propose MU methods based on a class-mean features classifier, which explicitly enforces alignment between features and classifiers.

-  **Student Researcher: Altay Unal, Doctoral**
-  **Faculty Advisor: Akshay Rangamani**
-  **Artificial Intelligence, Machine Intelligence & Robotics**



## #205 | FROM BRAIN NETWORKS TO NEXT-GENERATION AI: CONNECTIVITY AS A DESIGN PRINCIPLE

Artificial intelligence (AI) systems have achieved unprecedented performance across scientific domains; nevertheless, prevailing architectures in artificial neural networks remain largely disconnected from the multiscale organizational principles that characterize biological neural networks, the brain. While modern AI models optimize task-specific accuracy, they seldom integrate structured graph topology with nonlinear, time-evolving dynamics. In this work, we propose that connectivity, defined as the principled interaction between network structure and activity, should serve as a foundational paradigm for next-generation AI design.

We formalize three complementary dimensions of connectivity: (i) structural connectivity, representing the graph topology that constrains information flow; (ii) functional connectivity, capturing statistical dependencies arising from coordinated dynamics; and (iii) causal connectivity, characterizing directed influence and temporal predictability among nodes. Evidence from systems neuroscience suggests that better performance in biological networks emerge from sparse, modular, and dynamically reconfigurable interactions across these levels rather than from dense and uniform connectivity as most AI models.

Using biophysically plausible models of neural networks and simulations on these models, we hypothesize that reconstructing and integrating structural, functional, and causal connectivity provides actionable priors for AI architecture design. Structural constraints promote sparsity and modularity; functional metrics enhance representation alignment and synchronization; causal inference enables direction-aware learning and improved temporal credit assignment. When embedded into graph-based and spiking neural frameworks, these multiscale connectivity principles yield models that are more adaptive, interpretable, and energy-efficient.

This work contributes to advancing a shift from static feedforward architectures toward dynamic, structured, and causally informed intelligent systems, bridging computational neuroscience and scalable AI.

 Student Researcher: Fernando Vera Buschmann, Doctoral

 Faculty Advisor: Vincent Oria

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## #206 | CAN SMART DECISIONS ALSO BE SAFE? AN AI APPROACH TO BALANCING REWARD AND RESPONSIBILITY

In many real-world situations — from healthcare and finance to autonomous systems — decisions must be both effective and responsible. Acting too cautiously may reduce potential benefits, while acting too aggressively may violate important safety limits. This project explores how artificial intelligence can learn to make smart decisions while staying within predefined boundaries.

We develop a learning system that continuously improves its choices based on experience, while ensuring that it does not cross safety thresholds. Instead of simply maximizing rewards, the system carefully balances performance with responsibility. Over time, it adapts to uncertainty, learns from outcomes, and adjusts its strategy to remain both efficient and safe.

Our results demonstrate that intelligent systems can explore new opportunities and improve performance without compromising safety constraints. This approach moves us closer to AI systems that are not only powerful, but also trustworthy and aligned with real-world requirements.

 Student Researcher: Sourav Ganguly, Doctoral




 Faculty Advisor: Arnob Ghosh

 Artificial Intelligence, Machine Intelligence & Robotics






## #207 | PARTITIONING PROMPTS FOR HIGHER EFFICACY IN NETWORK DESIGN WITH LARGE LANGUAGE MODEL

This work discusses the usage of Large Language Models (LLMs) for the purpose of Network Design and Configuration, and defines prompt-partitioning frameworks to decompose complex networking tasks into simplified and focused tasks an LLM can better evaluate. It proposes the usage of network partitioning and deliverable partitioning, which simplify the inherent number of network elements or deliverables, respectively in a prompt. The results highlight the strong relationship between the number of tasks an LLM is asked to undertake and the response correctness. They further emphasize the importance of prompt partitioning methodologies and showcase their impact on the overall performance of a model in relation to network configuration or implementation scenarios. Our work further evaluates various state-of-the-art LLM's and showcase the applicability of our proposed partitioning schemes to any LLM. Such results highlight the power of prompt-engineering and pave the way for automated network configuration systems. This work was presented in IEEE HPSR 2025, Osaka, Japan, May. 2025.

-  Student Researcher: Vishnu Komanduri, Doctoral
-  Faculty Advisor: Roberto Rojas-Cessa
-  Artificial Intelligence, Machine Intelligence & Robotics

## #208 | COOPERTRIM: ADAPTIVE DATA SELECTION FOR UNCERTAINTY-AWARE COOPERATIVE PERCEPTION




Cooperative perception enables autonomous agents to share encoded representations over wireless communication to enhance each other's live situational awareness. However, the tension between the limited communication bandwidth and the rich sensor information hinders its practical deployment. Recent studies have explored selection strategies that share only a subset of features per frame while striving to keep the performance on par. Nevertheless, the bandwidth requirement still stresses current wireless technologies. To fundamentally ease the tension, a proactive approach is taken, exploiting the temporal continuity to identify features that capture environment dynamics, while avoiding repetitive and redundant transmission of static information. By incorporating temporal awareness, agents are empowered to dynamically adapt the sharing quantity according to environment complexity. This intuition is instantiated into an adaptive selection framework, COOPERTRIM, which introduces a novel conformal temporal uncertainty metric to gauge feature relevance, and a data-driven mechanism to dynamically determine the sharing quantity. To evaluate COOPERTRIM, semantic segmentation and 3D detection are taken as example tasks. Across multiple open-source cooperative segmentation and detection models, COOPERTRIM achieves up to 80.28% and 72.52% bandwidth reduction respectively while maintaining a comparable accuracy. Relative to other selection strategies, COOPERTRIM also improves IoU by as much as 45.54% with up to 72% less bandwidth. Combined with compression strategies, COOPERTRIM can further reduce bandwidth usage to as low as 1.46% without compromising IoU performance. Qualitative results show COOPERTRIM gracefully adapts to environmental dynamics, localization error, and communication latency, demonstrating flexibility and paving the way for real-world deployment.

-  Student Researcher: Shilpa Mukhopadhyay, Doctoral
-  Faculty Advisor: Arnob Ghosh
-  Artificial Intelligence, Machine Intelligence & Robotics






## #209 | A CONTEXT-AWARE ASSISTIVE AI SYSTEM FOR PROACTIVE SUPPORT IN AGING INDIVIDUALS WITH COGNITIVE CHANGES

Designing technologies to support independence and social engagement among aging individuals with changing cognitive abilities, such as mild cognitive impairment (MCI) or dementia, has received significant attention in prior research. Most current assistive devices are reactive: they focus on safety monitoring or only give reminders after something goes wrong. As a result, there is limited support for proactive assistance that helps individuals make timely decisions. This work presents a context-aware assistive AI system that provides anticipatory support around everyday actions, demonstrated through a use case focused on supporting individuals when leaving the house. To mitigate potential privacy concerns, one of the known barriers to technology adoption among aging individuals, the system avoids continuous monitoring and instead triggers sensing only when relevant actions are happening or about to happen. In this implementation, the system uses a presence-based trigger at the door to detect when someone is present and activates sensing to identify a known individual. Once identified, the system reasons over personal schedule, time of day, and environmental conditions to infer the likely purpose of leaving. Using this context, the system offers timely, personalized suggestions, such as reminders related to upcoming planned activities or situation-appropriate prompts, to support everyday decision-making. These suggestions can help individuals feel prepared and confident in daily activities and better maintain their independence. We built a working software prototype, demonstrating the feasibility of proactive, context-driven assistance. By moving beyond reactive alerts to anticipatory support, this research addresses a gap in existing assistive approaches that largely respond only after difficulties occur. This work contributes toward AI systems that promote autonomy, confidence, and social engagement among aging individuals with cognitive changes.

-  Student Researcher: Susmitha Gurram, Doctoral
-  Faculty Advisor: Alisha Pradhan
-  Artificial Intelligence, Machine Intelligence & Robotics

## #210 | UNDERSTANDING EDUCATORS' PERCEPTIONS OF AI-GENERATED NON-CONSENSUAL INTIMATE IMAGERY

AI-generated non-consensual intimate imagery (AIG-NCII) is an emerging social problem due to the advancement of AI tools. While recent incidents in middle and high schools have highlighted the urgency of this issue, there is limited understanding of what concrete supports schools need to effectively address AIG-NCII. To fill this gap, we conducted an interview study with 20 educators in the U.S. and investigated their attitudes, experiences, and practices related to AIG-NCII. Educators expressed concerns about both students' and their own vulnerability, as AIG-NCII may cause moral decline among students, while educators themselves could become victims. Nevertheless, existing practices in schools are limited, and they lack both training and systematic policies. Challenges such as a lack of resources, unclear legal boundaries, and limited knowledge of AI make implementation difficult. The findings of this paper contribute to interactive educational tool design, curriculum design, and policy-making, especially regarding the need for multi-stakeholder strategies to address issues surrounding AIG-NCII.

-  Student Researchers: Tongxin Li, Katelyn Reyes, Liezeil Jimenez, Doctoral
-  Faculty Advisor: D. Wohn
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## #211 | ISM: INTELLIGENT MULTI-PATH SCHEDULER FOR MULTI-CAMERA NETWORKED SYSTEMS

Emerging immersive applications increasingly depend on multi-camera systems that capture and stream multi-view content over heterogeneous wireless links. Multi-view codecs such as MV-HEVC efficiently exploit spatial and temporal redundancies in compression. However, their dense dependency graphs make transmission highly sensitive to network dynamics. At the same time, modern immersive receivers are increasingly equipped with multiple heterogeneous access technologies (e.g., Wi-Fi and 5G), and are expected to aggregate these paths to sustain the high aggregate bitrate. However, distributing packets across paths with conventional multipath schedulers is insufficient. These schemes are content-agnostic, and fail to leverage the differential frame importance inherent in the multi-view prediction structure.

This paper introduces a structure-aware and Reinforcement Learning based scheduling framework for multi-view video delivery over multipath networks. We formulate the sender's scheduling task as a constrained optimization problem that jointly minimizes viewport-weighted distortion and synchronization drift under per-path rate limits. We then cast the problem as a Markov Decision Process and train an agent that directly decides, at each slot, which frames to transmit on which paths based on the video dependency structure and real-time path states. Experimental results show that ISM improves multi-view PSNR by about +3 dB in low rate regime (e.g., ~80 Mbps), while achieving higher inter-view balance. We also report viewport-weighted PSNR under a non-uniform viewport distribution, where ISM provides about +5 dB gain in low rate regime.

 Student Researcher: Alireza Mohammadhosseini, Doctoral

 Faculty Advisor: Coleen Popp

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## #212 | PARAMETER ESTIMATION OF A CONDUCTANCE-BASED NEURON MODEL IN 3XTG ALZHEIMER'S DISEASE MICE USING SEQUENTIAL NEURAL POSTERIOR ESTIMATION

Alzheimer's disease is a neurodegenerative disorder characterized by progressive cognitive decline. Growing evidence indicates that alterations in neuronal intrinsic excitability emerge prior to overt amyloid-beta and tau pathology, suggesting that ion-channel-level biophysical changes may be among the earliest contributors to disease progression. However, the specific conductance parameters underlying these changes remain poorly understood.

In this study, we developed a conductance-based model built upon Hodgkin-Huxley type formalism to identify biophysical parameter changes underlying abnormal action potential firing in medial prefrontal cortex neurons of 3xTg mice. The model incorporates nine ionic currents governed by 26 biophysical parameters. To fit this model to whole-cell patch-clamp recordings, we employed Sequential Neural Posterior Estimation, a simulation-based inference method that approximates posterior distributions of model parameters given observed summary statistics. 272 summary statistics derived from membrane potential traces and spike-timing features across eight current injection levels trained the density estimator, enabling likelihood-free Bayesian inference on individual neurons over a high-dimensional parameter space.

Statistical comparison of estimated parameters revealed sex- and layer-specific biophysical alterations in 3xTg neurons. In 3-month-old male layer V neurons, increased leak conductance and cell surface area underlie hypoexcitability. In 6-month-old female layer II/III neurons, reduced leak conductance combined with altered A-type Potassium inactivation gating drives hyperexcitability. In 6-month-old male layer II/III neurons, reduced half-activation voltage of fast Calcium-activated Potassium conductance corresponds with shortened afterhyperpolarization latency, corroborated by bulk RNA sequencing. This work demonstrates how simulation-based Bayesian inference can uncover ion-channel-level mechanisms of excitability dysfunction in Alzheimer's disease.

 Student Researcher: Jung Park, Doctoral




 Faculty Advisor: Casey Diekman

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## #213 | DECENTRALIZED SAFE PATH FOLLOWING FOR MULTI-QUADROTOR SYSTEMS

This work presents a decentralized control framework for safe path following in multi-quadrotor systems. Each agent is assigned a geometric path embedded in the state space and stabilized using Transverse Feedback Linearization (TFL) to guarantee path invariance. The TFL controller is reformulated as a QP constraint, and only the speed and yaw objectives are relaxed to maintain feasibility, while additional roll-pitch barrier constraints ensure invertibility of the decoupling matrix. To ensure collision avoidance and feasibility, we enforce Exponential Control Barrier Function constraints within the TFL-CBF-QP. The resulting controller preserves stabilization of the path-following manifold while guaranteeing forward invariance of safety sets in a fully decentralized architecture. Simulations demonstrate safe convergence of multiple quadrotors to intersecting paths without violating collision or roll-pitch constraints.

-  Student Researcher: Hamza Tariq, Doctoral
-  Faculty Advisor: Adeel Akhtar
-  Artificial Intelligence, Machine Intelligence & Robotics

## #214 | CERTIFIABLE SAFE RLHF: FIXED-PENALTY CONSTRAINT OPTIMIZATION FOR SAFER LANGUAGE MODELS




Ensuring safety is a foundational requirement for large language models (LLMs). Achieving an appropriate balance between enhancing the utility of model outputs and mitigating their potential for harm is a complex and persistent challenge. Contemporary approaches frequently formalize this problem within the framework of Constrained Markov Decision Processes (CMDPs) and employ established CMDP optimization techniques. However, these methods exhibit two notable limitations. First, their reliance on reward and cost functions renders performance highly sensitive to the underlying scoring mechanism, which must capture semantic meaning rather than being triggered by superficial keywords. Second, CMDP-based training entails tuning dual-variable, a process that is both computationally expensive and does not provide any provable safety guarantee for a fixed dual variable that can be exploitable through adversarial jailbreaks. To overcome these limitations, we introduce Certifiable Safe-RLHF (CS-RLHF) that introduces a cost model trained on a large-scale corpus to assign semantically grounded safety scores. In contrast to the lagrangian-based approach, CS-RLHF adopts a rectified penalty-based formulation. This design draws on the theory of exact penalty functions in constrained optimization, wherein constraint satisfaction is enforced directly through a suitably chosen penalty term. With an appropriately scaled penalty, feasibility of the safety constraints can be guaranteed at the optimizer, eliminating the need for dual-variable updates. Empirical evaluation demonstrates that CS-RLHF outperforms state-of-the-art LLM model responses rendering at-least 5x efficient against nominal and jail-breaking prompts.

-  Student Researcher: Kartik Pandit, Doctoral
-  Faculty Advisor: Arnob Ghosh
-  Artificial Intelligence, Machine Intelligence & Robotics






## #215 | DIGITAL FORGERY DETECTION

The rapid advancement of image editing tools and generative models has made verifying visual content increasingly challenging. Modern forensic systems must determine whether an image is authentic, synthetic, or manipulated, while also identifying altered regions and providing clear, human-interpretable explanations. However, many existing methods treat detection and localization as loosely connected tasks and often omit explanation altogether, which can lead to inconsistent predictions and limited trust in the system's outputs. This work proposes a unified, evidence-driven framework that integrates these objectives within a single reasoning process. The approach introduces a shared intermediate representation, called **\*\*evidence tokens\*\***, that captures manipulation-relevant information from transformer-based visual features. These tokens form a common reasoning state that jointly drives image-level classification, supports precise localization of altered regions, and enables coherent natural-language explanations grounded in the same evidence. By explicitly aligning global decisions with localized evidence, the framework improves reliability, interpretability, and cross-dataset generalization under realistic perturbations. Overall, it advances trustworthy visual forensics in the era of generative AI by tightly coupling detection, localization, and explanation into a cohesive model.

-  Student Researcher: Mehri RezaeiAliabadi, Doctoral
-  Faculty Advisor: Frank Shih
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## #216 | HUMAN-IN-THE-LOOP TRAINING FOR TYPE III SOLAR RADIO BURST IDENTIFICATION

Solar radio bursts frequently accompany energetic solar phenomena, making them powerful diagnostics of fundamental processes on the Sun and excellent tracers for solar energetic particles, one of the most important sources of space weather hazards. In particular, reliable identification of type III solar radio bursts is critical for space weather applications, motivating the use of machine learning (ML) approaches for automated detection. However, training high-performing ML models is often expensive and time-consuming due to the need for large, expertly labeled datasets. This project presents a human-in-the-loop (HITL) framework for efficient training of machine learning models using data from the state-of-the-art Owens Valley Radio Observatory's Long Wavelength Array (OVRO-LWA). The proposed approach employs a You Only Look Once (YOLO) ML architecture initially trained on a small labeled dataset, which is iteratively expanded through targeted expert labeling guided by model uncertainty. By integrating active learning principles, this framework accelerates dataset growth while reducing labeling effort, enabling robust identification of type III solar radio bursts to enable robust space weather applications in the future.

-  Student Researcher: Anastasia Kuske, Doctoral
-  Faculty Advisor: Bin Chen
-  Artificial Intelligence, Machine Intelligence & Robotics

## #217 | DEVELOPMENT OF AN IMITATION LEARNING-BASED HUMAN-BACK EXOSKELETON INTERACTION SIMULATION FRAMEWORK

Work-related musculoskeletal disorders, particularly low back pain associated with repetitive manual material handling, remain a significant occupational health concern. Lower-back exoskeletons have shown potential to reduce lumbar loading; however, their effectiveness depends on the complex interaction between assistive torque delivery and human movement adaptation. This study proposes a scalable simulation framework to model human-exoskeleton interaction during load lifting by integrating a musculoskeletal human model and a lower-back exoskeleton within the MuJoCo physics engine. The exoskeleton's geometry and inertial properties are derived from its CAD model and coupled to anatomically corresponding human segments using rigid constraints and compliant spring-damper elements to represent soft tissue interfaces. The combined system will be formulated as a constrained dynamic model with assistive torques applied at the hip joints. Imitation learning will be employed to generate realistic lifting motions from motion capture reference trajectories, training a policy to minimize joint tracking error while ensuring dynamic consistency and smooth control outputs under both unassisted and assisted conditions. This framework will allow interaction forces and movement adaptations to emerge naturally from coupled dynamics and will be validated against experimental human-subject data. The proposed approach will provide a flexible, data-driven platform for analyzing biomechanical effects of exoskeleton assistance, evaluating trade-offs between load reduction and movement adaptation, and supporting future optimization of exoskeleton design and control strategies.

 Student Researcher: Dan Yan, Doctoral

 Faculty Advisor: Wei Yin

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## #218 | ADAPTABLE LOCAL-LLM CHATBOTS FOR ACADEMIC WRITING & CRITICAL AI LITERACY

Integrating generative AI (GenAI) into education offers substantial potential to refine academic and professional writing pedagogy. Many institutions categorize unmediated LLM usage as an integrity violation because models frequently produce informationally dense prose yet lack the interactive engagement necessary for persuasive writing (Jiang & Hyland; Markey et al., 2025). These outputs offer a sycophantic confidence that provides misleading cues to students while failing to address the rhetorical expectations of specific genres (Trainor, 2026). This research presents a chatbot prototype utilizing Gemini 3 Flash and Retrieval-Augmented Generation (RAG) to support the diverse disciplinary writing requirements at NJIT. Unlike base models and standard GenAI tools, this system uses rhetorical prompting (Ranade article CITE) and evidence-based best practices for writing pedagogy to promote metacognitive awareness for specific course outcomes, emphasizing student autonomy and constraining the underlying LLM parameters with fine-tuned prompting. We plan to collect and analyze interaction data to assess skill acquisition and intended learning outcomes. Ultimately, this approach enables professional communicators to develop genre-specific AI assistants for global applications.

 Student Researcher: Sana Anwar, Undergraduate

 Faculty Advisor: Michael Laudenschick

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## #219 | PREDICTION OF MAGNETIC FLUX EVOLUTION DURING SOLAR ACTIVE REGION EMERGENCE USING LONG SHORT-TERM MEMORY NETWORKS

Solar active regions (ARs) are the primary drivers of space weather events, making their early prediction crucial for operational forecasting systems. We develop machine learning models to predict the evolution of magnetic flux during AR emergence using 1D time series of the continuum intensity and acoustic power for 53 active regions and their surrounding quiet-Sun areas. Each observable is sampled over a fixed  $30.66 \times 30.66$  field of view, capturing the temporal evolution of the active region for training and validation of the MagFluxLSTM and MagFluxEnc-Dec models. The MagFluxLSTM architecture implements a single-stage standard Long-Short Term Memory (LSTM) network. MagFluxEnc-Dec represents an LSTM encoder-decoder with teacher forcing. To test and evaluate the models' performance, we use the continuum intensity and acoustic power maps (calculated from Doppler velocity) as input to predict the magnetic flux. Among the top 100 hyperparameter configurations ranked by validation derivative RMSE, 98% correspond to MagFluxLSTM, compared to only 2% for MagFluxEnc-Dec. Thus, although the MagFluxEnc-Dec architecture has higher model complexity, it leads to poorer generalization to unseen ARs and less stable training than the simpler MagFluxLSTM, which can predict magnetic flux emergence 3 – 10 hours ahead for a 12-hour-ahead window in both experimental and operational settings for the 5 testing active regions.

-  Student Researcher: Eren Dogan, Undergraduate
-  Faculty Advisor: Mengjia Xu
-  Artificial Intelligence, Machine Intelligence & Robotics

## #220 | SYSTEMATIC CONSTRUCTION OF TEXT ATTRIBUTED GRAPHS

Text-Attributed Graphs (TAGs) are emerging as a powerful data structure for artificial intelligence systems, combining the relational insights of network data with the semantic content of natural language. As we enter a data-rich era where both textual and relational information are indispensable for improving predictive modeling, TAGs hold enormous potential. Yet, progress is hindered on two fronts: dataset construction, since there is limited research on systematic methods for building TAGs from relational datasets; and interpretability, since current models working with these data types, such as large language models (LLMs) or graph neural networks (GNNs), often operate as dense black boxes. In this work, we address both challenges: we propose, train and test a comprehensive domain-agnostic framework by developing thousands of text-attributed graphs for a variety of machine learning tasks and statistically quantify the influence of construction choices on downstream predictions using decision tree analysis. Our results provide a prescriptive set of rules for optimal graph construction, offering a principled methodology for developing interpretable and high-performing backbones for modern AI systems.

-  Student Researcher: Amiri Hayes, Undergraduate
-  Faculty Advisor: Kristina Wicke
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## #221 | RGE-GCN: RECURSIVE GENE ELIMINATION WITH GRAPH CONVOLUTIONAL NETWORKS FOR RNA-SEQ BASED EARLY CANCER DETECTION

Early detection of cancer plays a key role in improving survival rates, but identifying reliable biomarkers from RNA-seq data is still a major challenge. The data are high-dimensional, and conventional statistical methods often fail to capture the complex relationships between genes. In this study, we introduce RGE-GCN (Recursive Gene Elimination with Graph Convolutional Networks), a framework that combines feature selection and classification in a single pipeline. Our approach builds a graph from gene expression profiles, uses a Graph Convolutional Network to classify cancer versus normal samples, and applies Integrated Gradients to highlight the most informative genes. By recursively removing less relevant genes, the model converges to a compact set of biomarkers that are both interpretable and predictive. We evaluated RGE-GCN on synthetic data as well as real-world RNA-seq cohorts of lung, kidney, and cervical cancers. Across all datasets, the method consistently achieved higher accuracy and F1-scores than standard tools such as DESeq2, edgeR, and limma-voom. Importantly, the selected genes aligned with well-known cancer pathways including PI3K–AKT, MAPK, SUMOylation, and immune regulation. These results suggest that RGE-GCN shows promise as a generalizable approach for RNA-seq based early cancer detection and biomarker discovery (<https://rce-gcn.streamlit.app/>).

 Student Researcher: Varsha Narayanan, Undergraduate

 Faculty Advisor: Mengjia Xu

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## #222 | MULTIMODAL ENSEMBLE MACHINE LEARNING FRAMEWORKS FOR HIGH-ENERGY SOLAR ENERGETIC PARTICLE EVENT CLASSIFICATION

High-energy solar energetic particle (SEP) events pose substantial risks to space exploration infrastructure. Accurate predictions of SEP events continues to be a challenge in space weather forecasting. In this work, we worked on extending an end-to-end ensemble machine learning framework for predicting 100 MeV SEP events by utilizing several optimization methods to improve the model's predictive performance.

Using a multimodal data approach for our framework we worked with space weather data including tabular, time-series, and polygon data. Using these datasets, we conducted a comprehensive study across individual models and the final ensemble model. We evaluated the impact of optimized configurations on model performance in balanced classification settings.

The purpose of this study is to provide a comparison of classification models based on distinct solar data modalities to demonstrate how utilizing end-to-end ensemble machine learning frameworks leads to measurable improvements in the accuracy of detecting solar energetic particle events. These findings show the importance of optimization in end-to-end ensemble learning pipelines and reinforce the value of multimodal data integration for advancing space weather prediction.

 Student Researcher: Geetha Pudukollu, Undergraduate




 Faculty Advisor: Bo Shen

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## #223 | FORECASTING CONTINUUM INTENSITY FOR SOLAR ACTIVE REGION EMERGENCE PREDICTION USING TRANSFORMERS

Early and accurate prediction of solar active region (AR) emergence is crucial for space weather forecasting. Building on established Long Short-Term Memory (LSTM) based approaches for forecasting the continuum intensity decrease associated with AR emergence, this work expands the modeling with new architectures and targets. We investigate a sliding-window Transformer architecture to forecast continuum intensity evolution up to 12 hours ahead using data from 46 ARs observed by SDO/HMI. We conduct a systematic ablation study to evaluate two key components: (1) the inclusion of a temporal 1D convolutional (Conv1D) front-end and (2) a novel 'Early Detection' architecture featuring attention biases and a timing-aware loss function. Our best-performing model, combining the Early Detection architecture without the Conv1D layer, achieved a Root Mean Square Error (RMSE) of 0.1189 (representing a 10.6% improvement over the LSTM baseline) and an average advance warning time of 4.73 hours, even under a stricter emergence criterion than previous studies. While the Transformer demonstrates superior timing and accuracy, we note that this high-sensitivity detection comes with increased variance compared to smoother baseline models. However, this volatility is a necessary trade-off for operational warning systems: the model's ability to detect micro-changes in precursor signals enables significantly earlier detection, outweighing the cost of increased noise. Our results demonstrate that Transformer architectures modified with early detection biases, when used without temporal smoothing layers, provide a high-sensitivity alternative for forecasting AR emergence that prioritizes advance warning over statistical smoothness.

-  Student Researcher: Jonas Tirona, Undergraduate
-  Faculty Advisor: Mengjia Xu
-  Artificial Intelligence, Machine Intelligence & Robotics

## #224 | QUANTIFYING THE PREDICTABILITY OF EPIDEMIC DYNAMICS: AN ENTROPY-AWARE EVALUATION OF FORECASTING MODELS




In this study, we quantified the predictability of epidemic dynamics by evaluating the forecasting performance of naive, statistical, machine learning (ML), and deep learning (DL) models across 13 multi-location weekly datasets. Our analysis focused not only on model accuracy but also on how the intrinsic properties of epidemic time series, measured by permutation entropy (PE) and weighted permutation entropy (WPE), influence model performance and forecasting error growth across increasing prediction horizons. We evaluated forecasting behavior using several metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), Symmetric Mean Absolute Percentage Error-based accuracy score (sMAPE acc), and Mean Absolute Scaled Error (MASE) for baseline-relative evaluation. We found a horizon-dependent outcome, measured by the count of locations where each model achieved the best forecast. At horizon 1, naive baselines such as LastValue were superior in the majority of locations. However, as the prediction horizon increased, machine learning (e.g., SVR) and deep learning (e.g., STGNN) models demonstrated superior performance in a growing number of locations. This trend suggests that while simple persistence models perform the best at short horizons, learning-based models exhibit lower error growth and are robust at extended forecasting intervals. Entropy values varied considerably across our datasets. While many series demonstrated high PE, indicating ordinal irregularity, consistently lower WPE values suggest that amplitude information introduces meaningful structure. Increasing entropy with delay indicated that recent observations are most informative for forecasting. Higher WPE was associated with greater forecasting difficulty across several settings.

-  Student Researchers: John Acosta, Rishik Reddy Yesgari, Undergraduate
-  Faculty Advisor: Lijing Wang
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## #225 | BEYOND SUBJECT-LEVEL VALIDATION: A LEAVE-ONE-DATA-SET OUT FRAMEWORK FOR GENERALIZABLE LEARNING

To investigate cross-dataset generalization under a leave-one-dataset-out framework, we combined 5 publicly available human activity recognition (HAR) datasets guided by the CAPTURE-24. In particular, we focused on datasets whose activity aligned most closely with leisure and free-living behaviors, as these activities reflect real-world variability and validity compared to tightly scripted laboratory tasks. By utilizing support vector machines, this study investigates deep learning architectures of LSTM, CNN, and TCN under a LODO framework. In addition to leveraging models capable of learning hierarchical temporal and spatial representations directly from raw sensor data, this work incorporates systematic hyperparameter tuning to optimize architecture-specific parameters such as kernel sizes, temporal receptive fields, and hidden state dimensions. This allows for a more expressive and adaptable modeling of complex motion dynamics across heterogeneous datasets. Importantly, evaluating these tuned deep models under LODO provides insight into whether performance gains arise from improved representational capacity or from reduced sensitivity to dataset-specific biases.




-  Student Researcher: Jian Kim, Undergraduate
-  Faculty Advisor: Jongsang Son
-  Artificial Intelligence, Machine Intelligence & Robotics

## #226 | MOTION SYNTHESIS AND KINETIC DATA EXTRACTION FROM MONOCULAR VIDEO: A PHYSICS-INFORMED SIMULATION APPROACH FOR BIOMECHANICAL ANALYSIS

Traditional biomechanical analysis is often restricted to laboratory environments equipped with expensive force plates and complex multi-camera optical motion capture systems, which require extensive setup time and specialized expertise. While recent advances in computer vision have enabled monocular pose estimation from standard video, these methods typically provide only kinematic geometry, lacking the kinetic data such as joint torques and ground reaction forces. This data is critical for exoskeleton design and robotic control. This research presents a novel framework that eliminates the need for high-cost hardware and tedious calibration processes. By integrating real-time monocular video input with a high-fidelity physics engine, our system synthesizes these non-observable biomechanical variables through a scalable, low-cost software interface.

Utilizing the Perpetual Humanoid Control (PHC) architecture within NVIDIA Isaac Gym, our tool maps human motion from a standard webcam or pre-recorded video onto a simulated humanoid model. By enforcing physical constraints such as gravity, mass distribution, and contact dynamics, the system “solves” for the forces required to replicate the observed motion. Initial testing demonstrates the successful extraction of joint torques, angular velocities, and ground reaction forces in real-time. For a simulated 79 kg subject, the framework accurately captures kinetic profiles during complex movements like squats and gait cycles.

The final application will provide a live dashboard for plotting these metrics, offering an easy, low-cost alternative to traditional/expensive gait labs. By providing high-fidelity kinetic insights from accessible video hardware, this project facilitates the rapid iterative development of assistive exoskeletons and provides a new pipeline for training bio-inspired robotic controllers. This approach significantly lowers the barrier to entry for clinical gait monitoring and personalized assistive device optimization.

-  Student Researcher: Christopher Rodriguez, Undergraduate
-  Faculty Advisor: Xianlian Zhou
-  Artificial Intelligence, Machine Intelligence & Robotics



## #227 | DEMOCRATIZING QUANTITATIVE MOTION CAPTURE FOR UBIQUITOUS USE: EVALUATING AN ARTIFICIAL INTELLIGENCE-BASED OPENCAP MARKERLESS SYSTEM IN COMPARISON TO A TRADITIONAL MARKER-BASED MOTION CAPTURE SYSTEM

Three-dimensional (3D) motion capture is widely used to quantify human movement. The gold-standard approach uses reflective markers, or small reflective balls, attached to key anatomical landmarks and tracked via infrared cameras. While accurate, this method is expensive, vulnerable to marker loss during complex movements, and largely confined to laboratory settings. As a result, motion capture for rehabilitation purposes is difficult in clinical environments with patients, limiting its practical application. OpenCap, a markerless motion capture system, offers a potential solution by using artificial intelligence and smartphone cameras to provide a low-cost, portable alternative suitable for home and community settings. However, its accuracy, particularly during multi-planar movements, remains insufficiently validated. This study evaluated the performance of OpenCap relative to a marker-based system during Bharatanatyam, a classical Indian dance form characterized by structured movements. Controlled experiments were conducted at the Life Sciences Motion Capture Laboratory at NJIT, where a participant performed standardized Bharatanatyam sequences while motion data were simultaneously collected using OpenCap and a Vicon marker-based system. Joint kinematics were compared using root mean square error (RMSE) to quantify agreement across joints. OpenCap demonstrated movement-dependent accuracy, with RMSE values for the hip, knee, and ankle ranging from 15.3°-15.5°, 5.4°-6.0°, and 8.4°-12.2°, respectively. Despite increased error in hip and ankle flexion, OpenCap consistently captured overall joint motion trends. These findings suggest that markerless motion capture can reliably quantify complex 3D movements, supporting its potential for expanded use in clinical and rehabilitation applications beyond laboratory settings.

 Student Researcher: Keerthana Venkatesh, Undergraduate

 Faculty Advisor: Saikat Pal

 Artificial Intelligence, Machine Intelligence & Robotics

## #228 | ECOFLIGHT: FINDING EFFICIENT ENERGY FLIGHT PATHS FOR AUTONOMOUS SENSING DRONES

EcoFlight is an energy-efficient path-planning algorithm designed for autonomous drones operating in three-dimensional obstacle-rich environments. As drone applications expand into environmental monitoring, disaster response, and infrastructure inspection, limited battery capacity remains a critical operational constraint. Traditional navigation algorithms primarily minimize geometric distance and often overlook realistic energy factors such as vertical climb costs, aerodynamic drag, acceleration, and hovering energy.

EcoFlight extends the classical A\* algorithm by incorporating a physics-based energy model directly into its heuristic function. The environment is represented as a 3D grid, and each flight segment's energy cost is computed using gravitational, drag, and kinematic equations. Rather than selecting the shortest path, EcoFlight determines the lowest-energy route while actively avoiding obstacles.

The algorithm was evaluated against Direct Path, Direct Path Distance A\*, and Rise and Traverse methods across simulated environments with obstacle densities of 30%, 50%, and 75%, at two flight speeds. Across 100 randomized trials per configuration, EcoFlight consistently achieved lower energy consumption than other obstacle-aware methods. Its performance advantage increased as obstacle density grew, demonstrating that minimizing distance alone does not guarantee energy efficiency.

EcoFlight provides a computationally feasible and physically grounded solution for energy-aware autonomous drone navigation, offering improved endurance and reliability in complex real-world environments.

 Student Researchers: Adrien Durasno, Tendai Chimuka, Undergraduate

 Faculty Advisor: Roberto Rojas-Cessa

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## #229 | A SYSTEMATIC EVALUATION OF AUTOMATIC METRICS FOR MEDICAL IMAGE CAPTIONING

The evaluation for automated radiology report generation is far behind compared to systems that automatically generate reports; comparative studies in this domain are continuing to rely on BLUE and ROUGE, two metrics developed for evaluation of machine translation that only show a poor correlation with clinical judgment. In this research survey, we cover sixteen evaluation metrics covering lexical overlap (BLEU, ROUGE, METEOR, CIDEr), semantic similarity (SPICE, Word Mover Distance, BERTScore), vision-language alignment (CLIPScore), clinical entity extraction (CheXpert-F1, RadGraph-F1, RaTEScore, RadCliQ), large language model (LLM) evaluators (GREEN, FineRadScore, RadFact) and expert radiologist evaluations. Each of these metrics are mathematically defined and include clinical domain examples of chest radiograph reporting. Since clinical metrics have pathology labels associated with them, they are much closer to what radiologists prefer. However, even though there is a strong correlation between clinical measures and radiologist judgment, they are limited by the fact that they are dependent on existing ontologies of the thoracic cavity. LLM-based methods provide interpretable classification of errors but suffer from large computational demands and fail at reproducibility. Even so, the sixteen metrics also have limitations since none of the metrics address diagnostic uncertainty, anatomical location, changes over time, or describe the degree of severity in reports all in one metric. To focus on the deficiencies of current metrics, a proposed framework was created: the Multi-Axis Evaluation Framework (MAEF). MAEF organizes evaluations into four distinct dimensions, linguistic quality, factual accuracy, visual grounding, and clinical usability. In addition, each dimension is evaluated under a formalized process, wherein candidates undergo a stringent screening process before being subjected to an extensive review process with costly evaluation processes. The research outcome places precedence on three research outcomes: the simplification of LLM measurement tools, expanding the clinical domain ontology to focus on CT and MRI, and establishing a benchmark framework that allows for comparison of diagnostic capabilities across different imaging modalities. This paper provides the current state of medical image captioning for both researchers developing new metrics and radiologists evaluating their candidates. Additionally, it outlines recommendations for improving the existing metrics to provide the most efficient and effective method to improve patient care.

 Student Researcher: Alexander Lidwin, Undergraduate

 Faculty Advisor: Fadi Deek

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## #230 | INTERFACE DESIGN AS CLIMATE INTERVENTION: USER TESTS OF THREE GREEN NUDGES IN CHATGPT TO REDUCE GENAI'S CARBON FOOTPRINT.

Every time we type a prompt into ChatGPT, energy is consumed: electricity powers data centers, water cools servers, and carbon emissions accumulate behind the scenes. As generative artificial intelligence (GenAI) becomes integrated into everyday work, its environmental footprint is growing rapidly. Yet, most conversations about sustainable AI focus on infrastructure and policy, not on how everyday user behavior might contribute to change. Based on a user-centered approach, we developed three ChatGPT prototypes that incorporated “green nudges”, interface design elements intended to promote more energy-conscious behaviors, without forbidding other options or adjusting incentives. These included 1) a Save Earth tool that provided prompting guidance, 2) a real-time Usage Tracker that displayed environmental impact, and 3) an EcoMode that introduced energy-aware processing delays. A 4-conditional between-subjects experiment (i.e., Save Earth tool vs. Usage Tracker vs. EcoMode vs. Control) with 219 participants suggests that the Usage Tracker and EcoMode could reduce prompt counts without compromising usability, compared to the current ChatGPT design. However, the SaveEarth tool remained ineffective as a green nudge, and suffered from low usability among infrequent ChatGPT visitors. This work reflects our interest in sustainable human-AI interactions and demonstrates how small design decisions may contribute to broader environmental impact as generative AI continues to scale.

 Student Researchers: Natalie Ramlall, Nurjahan Jhorna, Syeda Foyez, Undergraduate




 Faculty Advisor: Eugene Snyder

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## #231 | BATTERY AWARE DYNAMIC TOPOLOGY OPTIMIZATION (BA-DTO)

Networked battery systems arise in industrial automation, distributed energy applications, and multi-agent systems, where terminals consume energy locally and recharge only when connected to a source. Resource constraints often limit the number of simultaneous connections, requiring networks to be dynamically reconfigured to maintain system functionality. Managing such networks in dynamic environments is challenging, particularly when low-energy terminals must be prioritized for timely replenishment. This paper presents a battery-aware topology optimization algorithm that extends the GeoSteiner framework with a tailored Mixed-Integer Linear Program (MILP) formulation for Full Steiner Tree (FST) aggregation. The formulation minimizes network length while prioritizing low-battery terminals through a weighted objective subject to a global budget constraint, enabling partial network formation under realistic resource limits. An overlap-correction term is introduced that prevents double-counting when selected trees share terminals. To capture the network reconfiguration cost between time steps, a graph-distance metric penalizes frequent topology changes, resulting in 72.2% reduction compared to a baseline without penalty. Simulations on a 20-terminal network demonstrate battery levels are effectively managed as the lowest battery level improved from 2.7% to 68.6% over 30 iterations while maintaining the topology stability and budget utilization (92%). The framework offers a principled approach to designing energy-aware, adaptive connectivity in power-limited multi-agent systems.

-  Student Researcher: Pranay KC, Undergraduate
-  Faculty Advisor: SangWoo Park
-  Artificial Intelligence, Machine Intelligence & Robotics

## #232 | DEVELOPMENT OF AEROVE: A LIGHTWEIGHT MULTI-MODAL HYBRID ROBOT CAPABLE OF AERIAL-TERRESTRIAL LOCOMOTION

Inspection of pipelines for residual damage, gas leaks, and corrosion remains challenging due to confined geometries and the need to minimize human exposure to hazardous environments. Current inspection methods are outdated, costly, and often unreliable. My research focuses on the development of a lightweight hybrid robotic system, AeRove, to address these limitations through multi-modal mobility and sensing integration. AeRove combines aerial and terrestrial locomotion within a single compact system by converting its propeller guards into wheels, enabling a transition between flight and ground traversal in 200 milliseconds. Weighing less than 150g, AeRove is small enough to traverse pipelines of varying diameters while still maintaining a high level of robustness. The system's modular architecture allows adaptation to many applications through simple mechanical interchangeability. Low-level control and sensing are onboard, while the higher-level autonomy and data processing are executed via a Wi-Fi-connected base station. This work aims to establish a precise, adaptable, and scalable method for pipeline inspection.

-  Student Researcher: Caleb Polillio, Undergraduate
-  Faculty Advisor: Petras Swisler
-  Artificial Intelligence, Machine Intelligence & Robotics



## #233 | SEMI-AUTOMATED ROBOTIC ARM FOR MOTOR MAPPING

Transcranial magnetic stimulation (TMS) is a highly effective, non-invasive, and non-addictive brain stimulation modality that can be used to treat neuropsychiatric disorders and map functional brain areas, such as motor areas. However, manual operation of the machine is a lengthy process requiring highly trained operators to locate the motor hotspot, the area with the largest and most consistent motor-evoked potentials, and steadily hold a coil over the target for multiple hours. Minor changes to the coil location or orientation can lead to inaccurate and ineffective results. Meanwhile, the high cost of neuronavigation tools and operator training limits accessibility to TMS therapies. We propose an affordable robotic arm that semi-automates motor mapping using Bayesian optimization to improve TMS repeatability, accuracy, and access. The 6 degrees of freedom (6DOF) 3D-printed robotic arm provides stability and precise targeting throughout the duration of the TMS session and is made to utilize existing neuronavigation systems. The Bayesian optimization algorithm uses real-time electromyography (EMG) responses to update a Gaussian process regression surrogate model used to predict the motor hotspot location. It acts as the brain of the robotic arm, directing it to shift to the predicted locations on the subject's head iteratively until finding the motor hotspot used to ensure accurate motor mapping and effective treatment. Currently, the optimized motor hotspot search takes about 50% less iterations than manual navigated TMS alone. An optimized and semi-automated TMS robotic system could significantly improve the effectiveness of patient post-surgical or post-treatment outcomes and the accuracy of TMS research.

 Student Researchers: Isabella Arias, Owen Texter, Negar Namdar, Undergraduate

 Faculty Advisor: Elisa Kallioniemi

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## #234 | AUTONOMOUS SYSTEMS VALIDATION PLATFORM (ASVP)

Autonomous Systems Validation Platform (ASVP) is a modular, small-scale physical testbed designed to evaluate closed-loop hazard compliance in embedded autonomous vehicle systems. The platform integrates an NVIDIA Jetson Nano-based perception and decision stack with a remotely actuated traffic signal hazard to form a deterministic stop/go validation loop. ASVP enforces defined hazard-response contracts specifying state transitions, response timing thresholds, and failure conditions. System behavior is evaluated through synchronized logging of perception triggers, control commands, and physical actuation outcomes to generate reproducible evidence of compliance.

The current implementation focuses on a single controlled intersection scenario to isolate and validate the perception–decision–actuation pipeline before introducing additional hazards or network perturbations. The physical environment includes lane markings, stop zones, and modular hazard enclosures designed for repeatable experimental setup. By constraining scope to a deterministic validation case, ASVP emphasizes disciplined systems integration, subsystem interface definition, and measurable behavioral criteria rather than feature expansion.

ASVP serves as a foundation for structured sensor and control-stack evaluation within a controlled urban testing environment, enabling systematic analysis of autonomous system response integrity under clearly defined operating conditions.

 Student Researchers: Bartek Broclawik, Pola Szwaczka, Matthew Sudol, Undergraduate

 Faculty Advisor: Tao Han

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## #235 | MYCELIUM TO MACHINE: EXPLORING HYBRID INTELLIGENCE THROUGH CYBERPSYCHOLOGY

This research explores Mycelial Logic—the decentralized, adaptive intelligence of fungal networks—as a framework for evolving artificial intelligence from industrial tools into relational, ecological participants. Grounded in cyberpsychology, the study investigates how fungal behavioral patterns can inform ethical AI design. The methodology integrated biological observations of mycelial growth under environmental stressors with behavioral coding of AI-human dialogues. Findings demonstrate that mycelium utilizes non-linear strategies such as stalling and rerouting to navigate toxicity and scarcity. These patterns were abstracted to prototype SERA (Symbiotic Ethical Relational Agent), an agent capable of “ethical dormancy” and relational auditing. By reframing AI “hallucinations” as adaptive signals rather than errors, this work posits a shift toward hybrid intelligence based on mutualism rather than domination.

-  Student Researcher: KET-A Williams, Undergraduate
-  Faculty Advisor: Daniel Estrada
-  Artificial Intelligence, Machine Intelligence & Robotics



## #236 | SEMI-AUTONOMOUS SEARCH AND RESPONSE ROVER FOR DISASTER SCENARIOS

Collapsed-structure search and rescue operations are constrained by unstable terrain, obstructed visibility, and severe communication degradation caused by concrete, steel reinforcement, and debris. We propose a semi-autonomous two-wheeled ground rover augmented by a deployable, self-healing LoRa-based mesh communication network to address these limitations. The rover is designed for low-profile navigation in confined void spaces and incorporates compliant suspension and traction control optimized for rubble traversal.

A defining feature of the system is its ability to deploy compact ESP32-based mesh nodes throughout the environment, creating an adaptive communication backbone as it advances. This infrastructure enables persistent, low-bandwidth transmission of a prioritized “Person of Interest” (POI) signal—containing detection confidence, timestamp, and relative location—ensuring life-critical information is preserved even when full teleoperation or high-rate telemetry fails. The architecture is intentionally designed to degrade gracefully: when bandwidth drops, the system automatically prioritizes POI signaling and health status over mapping or video streams.

Control strategies incorporate robust state estimation, slip-aware traction management, and mesh-aware navigation to maintain mobility under uncertain terrain and intermittent connectivity. By integrating mobility, communication resilience, and human-in-the-loop supervision, the platform reduces responder exposure to secondary collapse hazards while accelerating victim localization.

This work demonstrates a scalable, competition-ready framework for resilient robotic deployment in communication-denied disaster environments and proposes a practical pathway toward fieldable, cost-effective urban search and rescue augmentation systems.




-  Student Researchers: Kevin Navarro, Cristian Garcia, Undergraduate
-  Faculty Advisor: Laramie Potts
-  Artificial Intelligence, Machine Intelligence & Robotics



## #237 | INTEGRATING PHYSICAL OBJECTS IN VIRTUAL REALITY TOWARDS TASK-SPECIFIC REHABILITATION

### *Sensor-fusion in virtual reality towards accurate hand interaction with physical objects*

Rehabilitation is most effective when it targets functional movements directly relevant to activities of daily living. However, many rehabilitation programs rely on repetitive, decontextualized exercises that lack real-world relevance, which can limit engagement and adherence. This project develops an innovative virtual reality (VR) rehabilitation platform that enables patients to interact with real physical objects while viewing precisely aligned virtual representations, supporting purposeful, task-oriented practice in an immersive environment. The system integrates computer vision-based VR hand tracking with inertial measurement unit data to achieve accurate spatial alignment among the patient's hands, a physical object, and its corresponding computer-aided design model in VR. Sensor fusion and calibration methods are designed to minimize latency and ensure natural interaction, while performance metrics, including grasp accuracy and release timing, quantify how effectively real-world actions map to the virtual environment. The project will ultimately produce a functional prototype that seamlessly integrates physical object interaction into VR-based rehabilitation. By combining motor practice with immersive, game-like experiences, this approach has the potential to increase patient motivation, improve adherence to therapy, and ultimately accelerate recovery.

-  Student Researchers: James An, Dominic Attalienti, Benjamin Porreca, Avanish Kulkarni, Undergraduate
-  Faculty Advisor: Roni Barak Ventura
-  Artificial Intelligence, Machine Intelligence & Robotics

## #301 | CONTINGENCIES OF EUSOCIAL BIOMASS IN MARINE ENVIRONMENTS

Eusocial animals dominate terrestrial environments in their abundance, biodiversity, and biomass. There are an estimated 20 quadrillion ants on Earth, surpassing the estimated biomass of wild birds and mammals. Termites, one of the largest natural methane sources, have a biomass comparable to humans. These outsized biomasses are a result of eusocial behavior; social insects like ants and termites exhibit reproductive division of labor. In a eusocial colony, only a small subset of individuals reproduce, while other “workers” engage solely in resource allocation. This divided labor results in more efficient resource allocation and extirpation of competing non-social species. Marine eusocial species are rare and subject to disparate physical factors. It is unclear whether they share similar patterns of estimated biomass, a proxy for ecological impact. We investigated the effect of eusociality on ecological dominance in marine environments. To achieve this, we estimated the biomass of pair-living, communal, and eusocial snapping shrimp from the genus *Synalpheus* at sites across the Caribbean. *Synalpheus* snapping shrimp are the only known eusocial lineages in the ocean. The biomass proportion of marine eusocial species diverges from patterns in terrestrial eusocial lineages like ants and termites. Limitations on nesting strategies in marine environments may contribute to lower eusocial biomass. Characterizing the ecological dominance of marine and terrestrial eusocial lineages informs potential drivers of social evolution and the factors that impact the composition of life on the planet.

-  Student Researcher: Claire Bailey, Doctoral
-  Faculty Advisor: Phillip Barden
-  Bioscience & Bioengineering



### #302 | DYNAMICS OF DOPAMINE DEPENDENT CORTICAL RHYTHMS ASSOCIATED WITH THE TREATMENT OF PARKINSON'S DISEASE

The Cortex-Striatal-Thalamic-Cortical (CSTC) circuit plays a key role in the regulation of motor, cognitive and emotional activities. In this work I developed a biophysically plausible conductance-based computational model that will be used to study the mechanisms behind the generation of neural oscillations in the circuit and its relationship with Parkinson's Disease (PD) as well as the system response under different settings.

The model consists of a system of non linear differential equations that follow the Hodgkin-Huxley formalism. These equations are solved computationally to simulate the activity of the Medium Spiny Neurons (MSN) and Fast Spiking Interneurons (FSI) of the Striatum and neurons from the Subthalamic Nucleus (STN), Globus Pallidus internus and externus (GPi and GPe) and the Thalamus (TH).

I studied the system's response to an external sinusoidal input and found that the MSNs have a firing rate resonance at two different frequencies, depending on the applied current and the synaptic inhibition provided by the FSIs. The MSN also show an entrainment to the input for a range of frequencies. These phenomena were present in simulations with low concentration levels of dopamine, associated with PD, suggesting a robustness in the circuits response, with the neurons of the STN acting as regulators of the activity of striatal neurons.

This is a first step in the study of the propagation of oscillations in the CSTC and the possible mechanisms behind it.

 Student Researcher: Isidro Gauto, Doctoral

 Faculty Advisor: Horacio Rotstein

 Bioscience & Bioengineering

### #303 | QUANTIFYING MORPHOLOGICAL CHANGES DURING POST-EMBRYONIC DEVELOPMENT OF MODEL CTENOPHORE MNEMIOPSIS LEIDYI

The ctenophore *Mnemiopsis leidyi* is an emerging model for exploring the evolution of embryonic development, regeneration, life history, and the nervous system. *M. leidyi* experiences significant morphological changes during its post-embryonic development. The ctenophore hatches as the "cydippid" body plan and remains this shape at a small size ( 5 mm). As their size increases beyond this point, *M. leidyi* and other "lobate" ctenophores grow new feeding structures which replace the use of external tentacles. This cydippid-to-lobate transition does not correlate with sexual maturation according to previous research, which differs from typical metamorphosis. The origins of multi-stage life cycles is a major area of ongoing research in zoology, and ctenophore phylogeny allows us to know that this second stage was added later in evolution of lobate ctenophores. Investigating this transition will inform our understanding of the evolution of metamorphosis and other kinds of life stage-specific morphologies in animals due to ctenophores' early branching phylogenetic position. We followed the development of individual *M. leidyi* from hatching to the lobate stage at different temperatures to further elaborate the described staging of normal development in this species. Furthermore, we measured allometric growth across this time course to detail the ontology of anatomical structures at different temperatures. These data will serve as a critical resource and reference for understanding ctenophore life history and post-embryonic development.

 Student Researcher: Yinghui Wang, Doctoral

 Faculty Advisor: Allison Edgar

 Bioscience & Bioengineering



## #304 | MECHANICS OF A SWEET ESCAPE: INVESTIGATING HOW BREAST CANCER REPROGRAM ITS SUGAR SHIELD

Breast cancer is a leading cause of death in women. Early diagnosis offers improved patient outcomes; however, survival rates plummet drastically with metastasis – the spread of the disease to distant organs, accounting for around 90% of all cancer-related deaths. Glycocalyx, a sugar-rich layer on the cell surface, mediates interactions with the cellular microenvironment. Cancer cells remodel their glycocalyx through hypersialylation, the addition of sialic acids by sialyltransferases, to evade the immune system during metastasis. This accounts for the reduced efficacy of CAR-T therapies in solid tumors. Several in vitro studies investigating this used supraphysiological glucose concentrations and rigid plastic surfaces, which fail to recapitulate physiologically relevant responses. To investigate how cancer rewrites its sugar shield under physiologically relevant conditions, we cultured healthy mammary epithelial MCF-10A cells on polyacrylamide hydrogels spanning stiffnesses representative of healthy and tumor tissues (400 Pa–60 kPa) under physiological (5 mM) and high (25 mM) glucose. Transcriptomic profiling and differential gene expression analysis revealed that most glycosylation-related genes were minimally responsive to stiffness under physiological glucose. Notably, ST6GALNAC4 and ST6GALNAC6 were selectively upregulated with increasing ECM stiffness, suggesting that they are stiffness-sensitive sialyltransferases of physiological relevance.

Our data further suggest that glucose availability modulates the cellular response at a level comparable to that of stiffness, revealing a previously underappreciated mechanometabolic crosstalk in cancer-associated glycosylation. Ongoing studies using CRISPR-Cas9 knockout and lentiviral overexpression in breast epithelial and cancer cells will define the functional role of these enzymes in glycocalyx remodeling, supported by lectin-binding assays and high-resolution imaging.

 Student Researcher: Toheeb Alao, Doctoral

 Faculty Advisor: Alexander Buffone

 Bioscience & Bioengineering

## #305 | ENGINEERING CELL SURFACE SUGARS TO CONTROL NEUTROPHIL ADHESION AND ROLLING

Neutrophils are immune cells that must attach to blood vessel walls before reaching sites of infection. This process is controlled by sugar molecules on their surface that enable interactions with vascular proteins. In this study, we use gene editing to modify key enzymes (ST3Gal-1 and ST3Gal-2) responsible for building these surface sugars. By knocking out or overexpressing these enzymes in neutrophil-like cells, we examine how changes in glycosylation affect cell rolling and adhesion under flow conditions. Our preliminary data suggest that engineering cell surface sugars can directly regulate immune cell adhesion, offering a potential new strategy to control inflammation in diseases such as sepsis.

 Student Researcher: Zeinab Amoabediny, Doctoral

 Faculty Advisor: Alexander Buffone

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### #306 | LOWER EXTREMITY JOINT FORCES DURING EXOSKELETAL-ASSISTED WALKING IN AN FDA-APPROVED EXOSKELETON: COMPARISON BETWEEN SPINAL CORD INJURED AND ABLE-BODIED PARTICIPANTS

Wearable robotic exoskeletons are currently the only option to restore upright mobility in persons with spinal cord injury (SCI). However, exoskeletal-assisted walking (EAW) exposes this population to a greater risk of bone fracture due to the substantial bone loss resulting from chronic immobility. The increasing popularity of wearable robotic exoskeletons emphasizes the need for the quantification of joint loading during EAW, an important predictor of bone fracture in persons with SCI. As such, the overall goal of this study was to quantify hip, knee, and ankle joint forces during EAW in an FDA-approved exoskeleton to assess fracture risk in persons with SCI and improve user safety in commercially available devices. We combined 3-D motion capture experiments with computational simulations to compute lower-limb joint forces from a person with SCI and an able-bodied (AB) participant during EAW and unassisted walking (AB only). We validated our methods by comparing our joint forces during unassisted walking to published in vivo data. Our findings indicate that persons with SCI experience substantially lower joint forces at the hips, knees, and ankles during EAW compared to AB persons, primarily because of minimal muscle force contributions in persons with SCI. Our study provides a computational framework to quantify the forces exerted on the long bones of persons with SCI during EAW. This work provides the foundation for future evaluation of fracture risk in persons with SCI and user safety during EAW in commercially available devices.

 Student Researcher: Gabriela Bertozzi De Carvalho, Doctoral

 Faculty Advisor: Saikat Pal

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### #307 | MOTOR UNIT TRACKING USING STA-DERIVED MUAP: AMPLITUDE FIDELITY

Tracking individual motor units has the potential to provide insight into neuromuscular coordination at the most functional level of voluntary muscle contraction, followed by quantitative characterization of differences between healthy activation patterns and those altered in stroke and neurodegenerative conditions. Surface EMG signals recorded at clinical or experimental settings are decomposed into Motor Unit Action Potential (MUAP) trains of individual motor units for observation. Systematic evaluation of motor unit behavior requires observing the same motor unit over time. However, traditional decomposition algorithms do not guarantee the extraction of identical motor units across different EMG recordings of the same muscle. This makes Motor Unit Tracking (MU Tracking) challenging, as no biomarker has been systematically tested and validated for reliable characterization of motor units. Motor Unit signals recorded at the skin surface depend on the relative position between its innervation zone and the electrode, which is modulated by changes in muscle physiology. Thus, MUAPs extracted from surface EMG will also be affected by the changes in muscle physiology. The aim of the research is to assess whether MUAPs computed from Spike Triggered Averaging (STA) of surface EMG exhibit sufficient shape similarity to real MUAPs across varying force levels and physiological changes in muscle. Since EMG recordings lack ground truth, we simulated physiologically realistic MUAPs and corresponding discharge trains to synthesize HD-EMG signals for systematic comparison with STA-derived MUAPs. Our results show that STA-derived MUAP peak-to-peak amplitudes ranged from 0.02–0.15  $\mu\text{V}$  at 20% MVC and 0.02–0.52  $\mu\text{V}$  at 100% MVC. Peak-to-peak amplitudes demonstrated strong linear agreement with simulated MUAPs at both force levels (slopes  $\approx 0.97$  at 20% MVC and 0.95 at 100% MVC), indicating high amplitude fidelity across motor units. Absolute deviations were small, ranging from 0.0041–0.0062 at 20% MVC across 65 motor units and 0.0051–0.0173 at 100% MVC across 100 motor units, consistent with mild amplitude attenuation.

 Student Researcher: Fabliha Chowdhury, Doctoral

 Faculty Advisor: Jongsang Son

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### #308 | EEG-BASED CONNECTIVITY IN SECONDARY MOTOR AREAS ARE RELATED TO INCREASED FUNCTIONAL RECOVERY FOUR MONTHS POST-STROKE

This study examined how alterations in brain connectivity metrics during the first four months after a stroke relate to recovery of upper limb motor function in individuals post-stroke. Using a data-driven approach, we explored the relationship between changes in resting-state EEG-derived brain connectivity and improvements in motor function, as assessed by the Fugl-Meyer Assessment (UEFMA). We also explored how baseline connectivity relates to changes in UEFMA.

Resting-state EEG data were collected within the first month after stroke and again at four months post-stroke for thirty-seven individuals. Connectivity metrics were analyzed across the Theta, Alpha, Beta1, Beta2 and Gamma frequency bands. Correlation analyses and modeling were employed to identify the brain networks most strongly associated with recovery. Results show a relationship between changes in brain connectivity among specific regions and improvements in UEFMA scores. Specifically, greater increase in connectivity between the precuneus and middle frontal gyrus correlate with higher recovery. Baseline IPL-MFG connectivity in the affected hemisphere correlates with increased UEFMA, while the affected precuneus and dorsal premotor areas show similar relationships. Comparison of node strengths for each studied ROI at 4 months versus baseline revealed that dorsal premotor node density in the unaffected hemisphere increases across all frequency bands. These results reinforce the value of exploring EEG-based metrics to inform individualized treatment approaches, underscoring the critical role of engaging the affected hemisphere in post-stroke recovery.

 Student Researcher: Michael Glassen, Doctoral

 Faculty Advisor: Sergei Adamovich

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### #309 | EXPLORING THE MOLECULAR MECHANISM UNDERLYING UPSTREAM MIGRATION IN NEUTROPHILS

The recruitment of peripheral blood cells to distal sites during acute inflammation is a key aspect of the immune response. But prolonged acute inflammation is highly toxic, causing tissue damage and becoming the root cause of many deadly diseases like cancer, diabetes, cardiac and lung disorders, and kidney diseases. It is estimated that 34.6% of US adults are suffering from some form of systemic inflammation. So, understanding the role of innate immune cells, such as neutrophils and macrophages, in peripheral blood becomes the need of the hour to precisely control and track their movement through blood vessels to reach the site of inflammation. This movement along the endothelial walls of blood vessels, governed by the leukocyte adhesion cascade, occurs through a cytokine-driven interaction between the surface integrins on immune cells and the endothelial adhesion ligands before transmigrating through the lamina and reaching the site of inflammation. Previous research from our lab has suggested that neutrophils, T-cells, and macrophages crawl on the endothelial ligands with the help of their surface integrins, sometimes flow against the shear flow of blood in a process termed as upstream migration. We have also shown that CD4+ T lymphocytes, Hematopoietic Stem and Progenitor cells (HSPCs), Marginal Zone B cells, and, with Mac-1 integrin inhibited, neutrophils and macrophages can migrate against the direction of shear flow on ICAM-1 surfaces, ICAM-1 and VCAM-1 mixtures, and stimulated Human Umbilical Vein Endothelial Cell (HUVEC) monolayers. It has been demonstrated that this form of upstream migration doubles transmigration speed when compared to crawling downstream. This finding also suggested that, through cytoskeletal rearrangement, upstream migration may accelerate extravasation and shorten the time it takes for immune cells to reach inflammatory areas. But to this point, our studies of upstream migration have relied on isolated primary cells and cell lines, so there is limited knowledge of which peripheral blood cells may crawl upstream on ICAM-1 to aid in combating inflammation. Building on these findings, our core hypothesis is that gaining a fundamental understanding of which and how immune cells migrate upstream on the genomic, signaling, and biophysical levels in both well-defined microfluidic and in-vitro assays of acute inflammation will allow for precise control of cell migration and allow faster transmigration.

 Subham Guin, Doctoral

 Faculty Advisor: Alexander Buffone

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### #310 | TARGETED DISRUPTION OF ORAL BIOFILMS USING PHAGE-NANOPARTICLE CONJUGATES

Dental caries, one of the most prevalent chronic diseases worldwide, are driven by biofilms dominated by *Streptococcus mutans*. These dense, acidogenic biofilms exhibit remarkable resistance to antimicrobial therapies and mechanical removal due to their extracellular matrix and strong adhesive properties. While lytic bacteriophages provide a promising, highly targeted approach, their efficacy is often constrained by poor biofilm penetration and rapid clearance. Conversely, conventional nanoparticle-based photothermal therapy (PTT) against oral biofilms would constitute a nonspecific intervention that risks destroying commensal oral microbiota.

To address these limitations, we propose a novel platform that enhances phage-mediated killing of *S. mutans* by conjugating lytic phages to bimetallic Au-Ag nanostars, thereby improving biofilm access and retention. In addition, we will test the bactericidal effects of photothermal therapy (PTT) using the NP-phage conjugates delivered to biofilms. We selected two lytic phages (M102AD, M102) for their activity against *S. mutans* serotype c strains, which represent 70-80% of the *S. mutans* strains found in the oral cavity. We seek to conjugate phages and nanoparticles by carbodiimide crosslinking via EDC to form stable amide bonds between carboxyl and amine groups. Reaction conditions are optimized for high conjugation efficiency and preservation of phage infectivity, with typical bacteriophage input of ~10<sup>9</sup> PFU/mL.

We hypothesize that NP-phage conjugates will achieve deeper biofilm penetration and enhanced bactericidal activity in *in vitro* *S. mutans* biofilms compared to phages alone. By leveraging nanoparticle physicochemical properties, such as size, charge, and surface chemistry, this approach may further enable modular delivery of imaging agents or adjunctive therapeutics. Together, this platform represents a promising direction for precision-targeted antibiofilm strategies. Pending experimental validation, NP-phage conjugates could emerge as a novel intervention for cariogenic biofilms and other persistent infections involving biofilm-forming pathogens.

 Student Researcher: Aviv Hargil, Doctoral

 Faculty Advisor: Maryam Hajfathalian

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### #311 | SHAPE-ENGINEERED GOLD-PALLADIUM NANOSTRUCTURES FOR IMAGING-GUIDED PHOTOTHERMAL THERAPY OF DRUG-RESISTANT BIOFILM INFECTIONS

Antimicrobial resistance (AMR) is a major global health threat, with drug-resistant and biofilm-associated infections posing significant therapeutic challenges. Biofilms formed by *Pseudomonas aeruginosa* are particularly difficult to eradicate due to limited antibiotic penetration, enhanced bacterial tolerance, and persistent resistance mechanisms. This project focuses on engineering gold-palladium nanostructures with controlled physicochemical properties to develop an imaging-guided photothermal strategy for treating drug-resistant biofilm infections.

Plasmonic gold components provide strong near-infrared (NIR) absorption, enabling photothermal therapy (PTT) and photoacoustic (PA) imaging, while palladium contributes intrinsic antibacterial and nanozyme-like catalytic activity. Gold-palladium nanostructures are synthesized using seed-mediated growth and/or galvanic replacement methods with controlled size and morphology. Structural and compositional characterization is performed using transmission electron microscopy, energy-dispersive X-ray spectroscopy, and ultraviolet-visible spectroscopy.

Photothermal performance is quantified through temperature elevation and photothermal conversion efficiency under NIR irradiation. Photoacoustic and computed tomography imaging evaluate multimodal imaging capability. Antibacterial efficacy is assessed using ZOI, MIC, and MBC assays against *Pseudomonas aeruginosa*. Peroxidase-like activity is measured spectrophotometrically via TMB oxidation. Biofilm eradication under NIR irradiation is evaluated using viability and regrowth assays.

This integrated theranostic approach aims to combine photothermal therapy, catalytic antibacterial mechanisms, and multimodal imaging to advance next-generation nanoplatforms for combating drug-resistant infectious diseases.

 Student Researcher: Ehsan Heidari, Doctoral

 Faculty Advisor: Maryam Hajfathalian

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### #312 | PHASE-DEPENDENT TMS-EEG REVEALS PEAK-TROUGH DIFFERENCES IN EARLY CORTICAL RESPONSES

The response to transcranial magnetic stimulation (TMS) varies from pulse to pulse and may depend on the instantaneous phase of ongoing cortical oscillations at the time of stimulation. While phase-targeted TMS can modulate corticospinal excitability, it remains unclear whether the oscillatory phase at TMS delivery similarly gates cortical reactivity measured with TMS-EEG. We tested whether sensorimotor mu phase at TMS onset modulates post-TMS cortical responses quantified using time-frequency EEG metrics. Healthy participants ( $N = 15$ , age  $25.06 \pm 3.9$  years) received 100 single-pulse TMS over the left primary motor cortex (M1) hand area at 90% rMT while EEG was recorded using a 64-channel system (Bittium NeurOne). EEG epochs were time-locked to TMS onset. For each trial, the EEG signal was bandpass-filtered in the mu band and the instantaneous phase at TMS onset was estimated using the Hilbert transform; trials were stratified into peak-phase versus trough-phase. For each phase group, event-related spectral perturbation (ERSP) was computed and averaged within the P30 window across mu, beta, and full bands. Within-subject paired t-tests compared peak versus trough conditions. A phase effect was confined to the P30 window: trough-phase trials showed significantly higher ERSP than peak-phase trials in mu ( $p = 0.0267$ ), beta ( $p = 0.0020$ ), and full ( $p = 0.0269$ ) bands, with the largest effect in beta. No significant peak-trough differences were observed for ERSP measures extracted from the N100 window. These findings support phase-informed, closed-loop TMS strategies to more consistently engage early cortical responses.

 Student Researchers: Mohammad Hosseinalizadeh, Kutluhan Mahmat, Elisa Kallioniemi, Doctoral  
 Faculty Advisor: Elisa Kallioniemi  
 Bioscience & Bioengineering

### #313 | ULTRASOUND TRIGGERED PHAGE-LIPID NANODROPLET CONJUGATE FOR ENHANCED AND TARGETED BIOFILM ERADICATION

Abstract: Antimicrobial resistance complicates the treatment of biofilm infections in chronic wounds due to extracellular polymeric substance (EPS) matrix. Bacteriophages which are basically viruses that parasitize bacteria, are adaptable platforms which only target their unique bacterial host species without infecting human cells. Phages face the risk of recolonization, increasing the likelihood of incomplete treatment and bacterial regrowth. In this context, lipid nanodroplets (LND) can be a potential biodegradable platform providing more direct antibacterial effect through physical interaction, making them effective in targeting bacterial cells with less susceptibility to immune system due to PEGylated surface. When exposed to focused ultrasound, these lipid nanodroplets can be converted into microbubbles through acoustic droplet vaporization (ADV), consequently resulting in microstreaming, shear forces, and cavitation, which disrupt the biofilm matrix and enhance drug delivery to deeper layers. In this study, OMKO1 phage conjugated lipid nanodroplets (CLD) have been developed to target *P. aeruginosa* biofilms where the phages target the bacteria, guide the LNDs to the biofilm and LNDs will be activated using ultrasound to effectively kill the biofilm bacteria. We developed two formulations. One contains DPPC, DOTAP, and PEG and enables electrostatic binding through charge interactions. The other one contains DPPC, PEG, and  $\text{NH}_2$ -PEG and uses EDC/NHS click chemistry forming covalent bonds. Transmission electron microscopy (TEM) confirmed successful conjugate formation. Antibiofilm assays were performed to quantify the infectivity of OMKO1 after and before conjugation with LND. In addition, confocal microscopy with fluorescently labeled droplets and phages visualized penetration depth and effective LND deliveries into biofilm.

 Student Researcher: Saima Islam, Doctoral  
 Faculty Advisor: Maryam Hajfathalian  
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### #314 | SUGAR TENSION IN BRAIN TUMORS IS CATASTROPHIC: DON'T SUGARCOAT IT.

Glioblastoma multiforme (GBM) is one of the most aggressive brain cancers and is characterized by a bulky glycocalyx that mechanically tensions the cell membrane and fuels tumor aggression. Historically, sugar components on red blood cells were used for blood typing, and subsequent pathological studies revealed differential sialic acid expression in cancer compared to normal tissues. Today, it is well established that most cancers exhibit increased glycosylation, resulting in an expanded, negatively charged glycocalyx enriched with sialic acids. In over 95% of cancers, this charged sugar coating promotes cell–cell and cell–matrix repulsion, generating piconewton-scale forces that activate integrin-mediated focal adhesion signaling and enhance migration, invasion, and proliferation. The glycocalyx is synthesized by glycosyltransferases that generate three major glycan classes: N-linked and O-linked glycoproteins, and glycolipids. However, the specific contribution of each glycan class to GBM metastasis remains unclear. A major limitation has been the inability to precisely edit glycocalyx composition; current approaches including small-molecule inhibitors, metabolic labeling, and gene silencing are often nonspecific or incomplete. Our long-term goal is to identify key glycan-initiating enzymes that regulate glycocalyx bulk and metastatic behavior in GBM. Preliminary data suggest that specific glycan chains drive glioma aggressiveness. We hypothesize that enzymes initiating N-, O-, or glycolipid glycans promote invasion by altering glycocalyx size and mechanics. This research will: (1) determine how each enzyme regulates glycocalyx architecture; (2) assess stiffness-dependent signaling and migration following glycan loss; and (3) evaluate stiffness-independent functional effects in U87 cells. This work will define actionable glycan targets for future immunoengineering strategies, including CAR-based approaches to sensitize GBM to therapy.

 Student Researcher: Funsho Habeeb Issa, Doctoral

 Faculty Advisor: Alexander Buffone

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### #315 | BIOMECHANICAL REGULATION OF MACROPHAGE PHENOTYPES VIA SHEAR FLOW INDUCED MIGRATION

During an inflammatory insult, leukocytes must traffic to the inflammatory site in order to perform their end-effector functions. Blood borne monocytes, recruited through chemokine activation, traffic to the site of inflammation by rolling on the endothelial surface, adhering to the endothelial surface and migrating along endothelial intracellular adhesion molecule 1 (ICAM-1) by their ligand's macrophage 1 antigen (Mac-1) and lymphocyte functional antigen 1 (LFA-1) to ultimately transmigrate through the endothelium. However, during chronic inflammatory conditions the recruitment of monocytes and macrophages becomes dysregulated leading to poor patient prognoses. Therefore, targeting the endothelial interaction between macrophages and the endothelial surface provides a novel approach to targeting the recruitment of macrophages and to tailor the arrival of certain macrophage phenotypes. To that end, we determined whether the loss of Mac-1 expression could induce this upstream migration behavior by utilizing blocking antibodies against Mac-1 to examine the effects of hydrodynamic flow on the migration of the human macrophage cell line U-937 on ICAM-1 surfaces. Here we found that blocking Mac-1 on U-937 derived macrophages led to their migration against the direction of hydrodynamic flow. As a result, identifying this new mode of macrophage motility invites new avenues into harnessing the upstream migration phenomenon to tailor the recruitment of macrophages to the inflammatory site, especially during chronic inflammatory conditions.

 Student Researcher: Aman Mittal, Doctoral

 Faculty Advisor: Alexander Buffone

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## #316 | PROTEIN-BASED NANOCOLLOIDS AS SYNERGISTIC ANTIVIRAL DELIVERY PLATFORMS

Viral infections, highlighted by the SARS-CoV-2 pandemic, underscore the need for post-infection therapeutics that complement vaccination. While vaccines are essential for prevention, they face challenges in rapid deployment, storage, and treating active infections. Protein-based antivirals such as monoclonal antibodies and peptides offer promise but are limited by high production costs, short half-lives, and reduced efficacy. To address these gaps, we present a protein-based nanocolloid (NC) platform that enables tunable, multifunctional antiviral activity with extended circulation time.

Our approach utilizes oleosin, a natural plant surfactant protein, as a scaffold for genetically appending viral entry inhibitors. Oleosin NCs were engineered to display S1-binding mini-proteins (LCBx) and/or anti-fusogenic IHR2 peptides, targeting both spike-ACE2 binding and TMPRSS2-mediated fusion. Recombinant constructs self-assembled into micellar and vesicular nanostructures, confirmed by electron microscopy and dynamic light scattering. Antiviral efficacy was evaluated against live SARS-CoV-2 Omicron using dsRNA staining and plaque assays.

Combinatorial treatment with Oleo-LCB3 and Oleo-IHR2 NCs demonstrated synergistic inhibition, outperforming monofunctional NCs and free peptide inhibitors. Enhanced efficacy is attributed to NC multivalency, steric blocking of virus-cell interactions, and improved stability.

This work establishes protein nanocolloids as a modular, scalable antiviral platform capable of targeting multiple stages of infection. The strategy enables rapid adaptation to emerging viruses and advances protein-based nanomedicine for post-infection therapeutic applications.

 Student Researcher: Giang Pham, Doctoral

 Faculty Advisor: Rajarshi Chattaraj

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## #317 | HAND JOINT ANGLE REGRESSION USING TRANSFER LEARNING BETWEEN FMG AND SEMG MODALITIES

Hand function is frequently impaired in individuals with neurological and musculoskeletal disorders such as stroke and arthritis, limiting independence and quality of life. Accurate estimation of hand joint angles from forearm muscle activity provides a non-invasive approach, with transformative potential for applications such as remote clinical assessment. Most publicly available datasets for joint angle estimation rely on surface electromyography (sEMG) and instrumented gloves. While sEMG is widely used, it has practical limitations, including high cost and sensitivity to sweat and hair, which limit practical applications. Alternative myographic modalities such as force myography (FMG), mechanomyography, and optical myography offer robustness but lack large datasets needed to train generalized deep learning models. To address this challenge, we propose a transfer learning framework that leverages large sEMG datasets to reduce data requirements for alternative modalities. As a first step, we trained a Long Short-Term Memory (LSTM) network on the MyoKi dataset, which includes 35 participants: 25 with only sEMG data and 10 with sEMG and FMG data. The model trained solely on sEMG achieved a validation RMSE of 0.71. To adapt it to FMG, the LSTM layers were frozen, and only the initial fully connected layer was retrained with the limited FMG data, reducing RMSE to 0.75 compared to 0.86 for a model trained solely on FMG. This demonstrates that pretrained sEMG features can improve prediction accuracy in data-scarce modalities. These preliminary results indicate that temporal muscle activation features learned from large sEMG datasets can transfer across modalities with minimal adaptation.

 Student Researcher: Sai Sriparna Thulluri, Doctoral

 Faculty Advisor: Jongsang Son

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## #318 | SPATIALLY CONTROLLED STEM CELL DIFFERENTIATION IN 3D-PRINTED SCAFFOLDS FOR OSTEOCHONDRAL TISSUE ENGINEERING

3D-printed biodegradable polymer scaffolds offer patient-specific architecture, controlled macroporosity (~500  $\mu\text{m}$ ), and robust mechanical support for implantation. However, achieving spatial and temporal control of biochemical signaling within these constructs remains a major challenge, particularly for complex interface tissues such as the osteochondral (OC) unit, where cartilage and bone require distinct yet coordinated cues. To address this, we developed a hybrid 3D printing strategy that integrates airbrushed gelatin methacrylate (GelMA) fibrous membranes within a 3D-printed polycaprolactone (PCL) framework. The GelMA/PCL and GelMA-HepMA/PCL hybrid scaffolds were fabricated successfully with controlled fibrous membrane density. The integration of fibrous membranes enabled spatial control of cell distribution and spatiotemporal release of BMP-2 or TGF- $\beta$ , which significantly enhanced osteogenic and chondrogenic differentiation of seeded hMSCs respectively. We have already developed continuous scaffolds with spatially controlled delivery of BMP-2 and TGF- $\beta$  to simultaneously promote osteogenic and chondrogenic differentiation spatially for osteochondral regeneration. Our ongoing studies focus on quantification of the functional outcomes of these scaffolds. Overall, our hybrid scaffolds offer a key advancement in spatially regulating stem cell differentiation within 3d printed scaffolds for osteochondral tissue engineering.

 Student Researcher: Thi Ngoc Hang Truong, Doctoral

 Faculty Advisor: Murat Guvendiren

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## #319 | AI-BASED AUTOMATED CLASSIFICATION FRAMEWORK FOR GENE VARIANT PATHOGENICITY

When a patient's genetic test reveals a DNA change, doctors face a critical question: does this change cause disease? The answer determines diagnosis and treatment, but currently requires clinical geneticists to manually review evidence using complex criteria that take 6–8 hours per patient. Geneticists must navigate a biomedical literature ecosystem exceeding 30 million publications, often spending up to 4 hours on literature review for a single variant. With more than 4 million variants already recorded in public databases and clinical testing volumes growing rapidly, expert review capacity cannot keep pace with sequencing technology, delaying cancer diagnosis and treatment decisions. This project aims to automate this process while maintaining expert-level accuracy.

We developed an automated AI framework that evaluates genetic variants following the same criteria used by clinical experts. The framework combines natural language processing, a structured rule engine, and genomic databases. It can systematically evaluate evidence from multiple perspectives, including population frequency, computational prediction, functional data, and clinical information. It can also output clear and reproducible classification results.

We tested this approach on a benchmark dataset annotated entirely by certified clinical geneticists. Our results demonstrate high consistency with expert classifications, with particularly robust performance on hereditary cancer variants in breast cancer related genes. This automated system reduces variant assessment time from 6–8 hours to minutes, enabling cancer patients to receive accurate diagnoses sooner. It helps overburdened geneticists focus on challenging cases and improves access to precision medicine for families facing hereditary disease risks.

 Student Researchers: Xun Song, Zhirong Zhang, Doctoral

 Faculty Advisor: Zhi Wei

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## #320 | A HOME-BASED DUAL-TASK COGNITIVE–MOTOR REHABILITATION PLATFORM FOR STROKE AND SPINAL CORD INJURY SURVIVORS

Neurological conditions such as stroke and spinal cord injury (SCI) often lead to persistent upper-limb impairment and cognitive deficits that jointly limit independence in activities of daily living. While many upper-limb robotic studies report kinematics and forces, attention, intention, and task strategy are rarely quantified in a synchronized and scalable way, and conventional cognitive screens (e.g., MoCA/MMSE) provide limited resolution for task-level performance. This project develops a home-deployable dual-task cognitive–motor rehabilitation platform that integrates a lightweight 3D-printed 3-DOF arm exoskeleton, a pneumatic rehabilitation glove, and an eye-tracking system. A Unity-based game framework provides standardized tasks and event timestamps (e.g., start/end, target onset, success/failure) to synchronize multimodal data streams, including gaze behavior, IMU/motion-capture kinematics, glove signals, and exoskeleton states. The platform enables objective measures of cognitive–motor interaction, such as time-to-acquire target, overshoot count, movement smoothness, reaction-to-motion latency, fixation dynamics, gaze shifts, and gaze–hand coordination timing. The project roadmap includes: (1) building and validating a passive integrated system to establish reliable cognitive testing and synchronization; (2) adding motorized actuation with assist-as-needed control to enable active rehabilitation training; and (3) recruiting participants for a first-in-human pilot to evaluate feasibility, safety, and outcome sensitivity. This project is supported by the Kessler Foundation.

 Student Researcher: Yuanhao Chen, Doctoral

 Faculty Advisor: Wei Yin

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## #321 | THE ROLE OF RECEPTOR-LIGAND COOPERATIVITY IN THE CELL ADHESION OF FUNCTIONALIZED NANOCARRIERS

Targeted drug delivery using functionalized nanocarriers (NCs) is a powerful approach for enhancing therapeutic precision. However, achieving effective NC binding remains challenging due to the complex interplay between cell surface characteristics and the physical properties of the carriers. This study investigates how receptor density, ligand affinity, and membrane mechanics collectively influence multivalent interactions, aiming to identify tunable parameters for enhancing carrier adhesion.

We employ a multiscale computational framework, integrating Monte Carlo simulations and thermodynamic analysis, to explore these dynamics across NCs with distinct mechanical properties: rigid and semi-rigid. Our findings reveal three key insights. First, receptor density directly modulates binding cooperativity, with higher densities significantly amplifying ligand-receptor engagement. Second, ligand affinity is crucial for stabilizing attachment; stronger interactions promote firm adhesion, whereas weaker interactions allow for dynamic exchange along the membrane. Finally, cell membrane mechanics drastically alter the binding landscape. Specifically, natural membrane fluctuations can either promote or hinder NC attachment.

Ultimately, this work provides a comprehensive understanding of the physical and biological factors driving targeted delivery. These computational insights contribute to the rational engineering of functionalized nanocarriers, advancing their application in complex biological environments.

 Student Researchers: Seyed Morteza Hamzeh Pahnehkolaei, Doctoral

 Faculty Advisor: Samaneh Farokhirad

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### #322 | MECHANICAL COMPETENCE OF BONE FROM PERSONS WITH SPINAL CORD INJURY: DEVELOPMENT OF A NON-INVASIVE FRAMEWORK TO QUANTIFY TORSIONAL AND COMPRESSIVE STIFFNESS AND STRENGTH

Individuals with spinal cord injury (SCI) experience rapid and progressive bone loss below the lesion, leading to significant bone resorption and osteoporosis induced fragility fractures. The gold standard method of bone competency are the radiographic measures of dual-energy x-ray absorptiometry (DXA). However, DXA does not account for the geometry, mineral distribution, mechanical properties, and mode of loading. Studies have shown that finite element (FE) can model these complex interactions to demonstrate superior accuracy. The objective of this study was to develop a non-invasive computed tomography (CT)- and FE-based computational framework to quantify four FE-based metrics of bone strength: torsional stiffness (Kt), torsional strength (Tult), compressive stiffness (Kc), and compressive strength (Cult) from persons with SCI and able-bodied (AB) control participants. We recruited 22 (15M, 7F) participants with SCI and 5 (4M, 1F) AB participants. We computed the four FE-based metrics of bone strength from CT scans of 43 SCI and 10 AB proximal tibias. Our methods used tetrahedral elements over conventional voxel elements to better capture the organic geometry of bone. Contrary to previous research suggesting bone strength is normally distributed, our findings indicate that these FE-based metrics are best described by a non-Gaussian, two-parameter Weibull model ( $R^2 \geq 0.92$  in all cases). The results from this study provide a foundation for statistical models fitting the distributions of FE-based metrics of bone strength, and confidence interval-based thresholds to predict fracture risk in persons with SCI and other osteoporotic populations.

 Student Researchers: William Kuo, Anmol Doss, Doctoral

 Faculty Advisor: Saikat Pal

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### #323 | RESONANCE-DRIVEN PHASE LOCKING AND TEMPORAL CODING IN CA1 PYRAMIDAL NEURONS

Neuronal rhythmic behavior is ubiquitous in the brain and occurs at different frequency ranges. Hippocampal neurons generate prominent theta and gamma oscillations that support temporal coding of spatial information, episodic memory, and learning. However, the biophysical mechanisms underlying these rhythms remain unclear. We investigate how intrinsic theta resonance in CA1 pyramidal neurons enables frequency selective phase locking of spiking patterns to theta and gamma oscillations, promoting coherent network activity. We show that these resonant dynamics can be regulated through tuning intrinsic and synaptic mechanisms that shape the transition between spiking and bursting, which support spatial and temporal coding. By modulating the interactions between intrinsic theta resonance and oscillatory synaptic inputs we are able to generate robust frequency specific phase locking in both theta and gamma bands. Additionally, we utilize Simulation-Based inference, a parameter estimation technique, to recover underlying biophysical parameters that govern resonance, spiking to bursting transition, and frequency specific phase locking. This approach allows us to mechanistically link between cellular properties and network level oscillation dynamics, offering insight into how hippocampal neurons coordinate temporally precise firing for spatial and memory coding.

 Student Researcher: Joshua Schreibeis, Doctoral

 Faculty Advisor: Horacio Rotstein

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## #324 | CORRELATING EXCITABILITY AND TASK-RELATED HEMODYNAMIC RESPONSES OF THE HUMAN CORTEX: A MULTIMODAL TMS-EEG-FNIRS STUDY



### *Correlating cortical excitability and hemodynamic responses: A multimodal TMS-EEG-fNIRS study*

Background: Transcranial magnetic stimulation (TMS) is a noninvasive brain stimulation, used to treat psychiatric disorders (e.g. anxiety and depression). However, TMS-evoked responses vary across subjects, reducing the effectiveness of TMS treatments. TMS activates neural responses, reflecting cortical excitability, which are measured by electroencephalography (EEG). Previous evidence shows that cerebral blood oxygenation (brain hemodynamic responses) can modulate neural responses, but understanding how brain hemodynamics predict individual variability in TMS-EEG (cortical excitability) remains unclear. The brain hemodynamics are increased by two well-studied motor tasks: finger tapping (FT) and breath holding (BH), and recorded using a functional near-infrared spectroscopy (fNIRS).

Objective: To test whether the task-evoked hemodynamic responses can predict inter-individual variability in TMS-evoked cortical excitability.

Method: Twenty-one healthy adults ( $25.71 \pm 4.63$  years old, 15 males) completed a TMS-EEG and a separate fNIRS session. First, 100 TMS pulses were delivered at 90% of the subject's individual motor threshold. Secondly, brain hemodynamic responses were recorded using fNIRS while subjects performed the FT and BH tasks. Inter-trial coherence (ITC) and event-related spectral perturbations (ERSP) were used to quantify the cortical excitability. Oxyhemoglobin (HbO), deoxyhemoglobin (HbR), and total hemoglobin (HbT) metrics were used to represent brain hemodynamics.

Results: Mu and beta band activity of TMS-EEG showed that ITC and HbO of FT, as well as ERSP and HbO of the BH, are positively correlated.

Conclusion: These results help our understanding of how much differences in hemodynamics can explain the observed between-subject variability in TMS-evoked responses.

 Student Researcher: Kutluhan Mahmat, Doctoral

 Faculty Advisor: Elisa Kallioniemi

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## #325 | ALTERNATIVE RECEPTOR PROFILES AND VIRAL ENTRY MECHANISMS IN THE HUMAN ORAL CAVITY

Despite over 800 million infections, SARS-CoV-2 remains a persistent threat as emerging variants increasingly bypass traditional ACE2-dependent entry. This shift suggests a reliance on alternative pathways, making it critical to investigate the oral mucosa, a key understudied portal of viral transmission. This project aims to characterize alternative receptor expression across distinct regions of the oral mucosa and determine how regional inflammatory signaling modulates these profiles to facilitate infection.

To establish a baseline, we determined the expression of a set of alternative receptors in healthy donor tissues and oral region-specific cell lines. Our findings reveal limited ACE2 expression alongside highly diverse, site-specific patterns of alternative receptors across gingival, buccal, and salivary gland tissues. This establishes a platform for functional knockdown studies to determine the specific contributions of these candidates to viral entry and immune activation. Furthermore, we explore how region-specific inflammatory signaling through targeted agonist stimulation reshapes these receptor profiles. By mapping these ACE2-independent pathways and their modulation by inflammation, this research provides a mechanistic framework for predicting tissue-specific vulnerability and informing the development of more durable, targeted preventive strategies against evolving variants.

 Student Researcher: Nilesh Das, Undergraduate

 Faculty Advisor: Yuanwei Zhang

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## #326 | STRENGTHENING THE DENTAL RESPONSE TO INTIMATE PARTNER VIOLENCE

Intimate partner violence (IPV; defined as physical, sexual, or psychological harm in the context of a romantic relationship) is a pressing issue that affects millions of people across the world. Early detection and response to IPV is critical, given that these outcomes often worsen over time. In the clinical setting, it may be possible to identify ongoing IPV through physical and behavioral cues, like bite marks/ bruises, unnecessary attendance of the partner at appointments, frequently missing appointments, and hesitation to speak when their partner is present. Because injuries associated with IPV are often on the head, face, and mouth, dental healthcare professionals are in a unique position to recognize signs of abuse. Research shows that a significant proportion of practicing dentists feel unprepared to respond appropriately when abuse is suspected. This project aims to strengthen dental response by developing a clinician-oriented white paper that will be sent out to dental practices in New Jersey, with a specific focus on practices who work with low-income/underserved populations. The paper will provide practitioners with information on how to identify any potential warning signs, conduct safe screenings, appropriately document the results of the examination, and connect the victims to the appropriate resources. It will also include recommendations for integrating IPV education into dental school curricula to address the root of the problem. That way, dentists will feel better prepared to respond to IPV effectively, and more victims can be identified and connected to the resources they need.

 Student Researcher: Mariam Eleish, Undergraduate

 Faculty Advisor: Abriana Gresham

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## #327 | MACHINE LEARNING AND STRUCTURE-BASED DRUG DESIGN TO DEVELOP SMALL MOLECULES TARGETING MITOCHONDRIAL PROTEASE LONP1 INHIBITORS AS CANCER THERAPEUTICS

Cancer is a leading cause of death worldwide, resulting in approximately 620,000 deaths in 2025. In the United States, nearly 2 million cases were identified. The common forms of cancer are breast, prostate, lung, and colorectal cancers. Cancer research focuses on understanding the mechanisms driving cancer cell survival and proliferation, and the development of innovative strategies for killing cancer cells using pharmacological agents, immunotherapy, or gene therapy. The oncogenesis and uncontrolled growth of cancer cells is driven by DNA damage or altered gene expression. Cancer cells require tremendous amounts of energy for survival and growth, which is produced by mitochondria. The mitochondrial ATP-dependent LONP1 protease has emerged as a potential anticancer drug target, crucial for mitochondrial metabolism, energetics, and proteostasis. In this research project, the Machine Learning platforms DrugGen, DrugFlow and FlexFlow. will be implemented with other molecular modeling platforms to identify and develop small molecule inhibitors of LONP1 with binding specificity and high affinity. Identified compounds will be evaluated using biochemical and cell-based assays to determine their respective efficacies in disrupting mitochondrial function and eliciting cancer cell death. The expected outcome of this project is the development of drug-like inhibitors of LONP1 with translational potential for anticancer therapeutics.

 Student Researcher: Gurnoor Kaur, Undergraduate

 Faculty Advisor: Carolyn Suzuki

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## #328 | AN EXPLORATION OF ANIMAL MODELS USED IN TRAUMATIC BRAIN INJURY RESEARCH; ARE WE LEAVING RODENTS IN THE PAST?



The primary cause of death and disability worldwide stems from traumatic brain injury. Such significance makes it a favorable field for research, specifically with the use of model organisms. Some traditional model organisms used in this field are rodents—rats and mice. However, difficulties in producing results that translate to humans has raised the question regarding the efficacy of using these models. Progress has been made as other organisms such as ferrets and swine are instead used to study the effects of these injuries. Here is presented a literature review, looking at the animal models used, aiming to optimize resources as we draw conclusions from organisms that allow successful translational research to humans. Additionally, the review will explore benefits and drawbacks of other organisms including exploring anatomical similarities, experimental methods, and accessibility. By having a relevant understanding of the research methods that backdrop the exploration of the brain's response, scientists can optimize the most effective research.

 Student Researcher: Jenny Ramzi, Undergraduate

 Faculty Advisor: Bryan Pfister

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## #329 | ENGINEERING CELL-MEDIATED DEGRADABLE BIOINKS FOR PERFUSABLE 3D TISSUE CONSTRUCTS

Tissue engineering aims to create viable tissue samples that could be used to repair or replace damaged organs. However, a major bottleneck that prevents tissue engineering from reaching this capability is the insufficient perfusion and lack of nutrient transport in thick 3D constructs. Without adequate perfusion, cells within the construct rapidly deteriorate, thus minimizing the function of the construct. One of the most prominent solutions to this issue has been the creation of channels within the 3D hydrogel constructs, which allows for the perfusion of cells within the construct. However, these channels are macro-scale and fixed at fabrication, which does not properly mimic native tissue vascular organization. In this project, we aim to solve this issue by inducing cell-mediated degradation that creates microchannels within the construct, thus increasing functionality by creating dynamic and biomimetic vascular structures within 3D constructs. In this approach, we use a cell-degradable material which allows for the dynamic remodeling that is observed in native tissue, where vascular networks are formed through cell-mediated matrix degradation and growth. To induce cell-mediated degradation, we will be using peptide crosslinkers which are cleaved by cellular enzymes during their proliferation. Therefore, as the cells proliferate, their external matrix degrades, which provides more space for them to grow. This creates spontaneous microchannels over time, which allows for angiogenesis.

 Student Researcher: Ali Salama, Undergraduate

 Faculty Advisor: Murat Guvendiren

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### #330 | A COMPARATIVE ANALYSIS OF SENSORY ORGANS IN SOCIAL SNAPPING SHRIMP

Social behavior and its consequences are exhibited across the animal kingdom as a result of variable drivers, such as ecological pressure and physiological mechanisms. *Synalpheus* snapping shrimp organize in a range of social groupings, from pair-living, to communal, to eusocial colonies. Containing numerous and recent independent origins of eusociality, the genus *Synalpheus* provides a unique framework for comparative studies to better understand the evolution of complex social living. To perceive and interact with their environment, snapping shrimp rely on multimodal sensing and mainly through organs such as compound eyes for vision and antennae for chemo- and mechanoreception. I will quantify the morphology of compound eye and antennae structures of *Synalpheus* specimens using a stereomicroscope and compare the sizes of these organs as a proxy for the sensory strength and ability across social syndromes. I will uncover how sociality shapes sensory organ trade-offs in snapping shrimp and how these trade-offs may impact the sensory ecology of social species. This study will provide insight into morphological and physiological adaptations of animals within the context of social evolution.

 Student Researcher: Kristina Camia, Undergraduate

 Faculty Advisor: Phillip Barden

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### #331 | BETTER TOGETHER? INTERACTION EFFECTS ON COLLECTIVE EXPLORATION

Exploration is crucial for both animals and humans and is heavily reliant on collective interactions when done in groups. Whether it be in the context of foraging or exploring new environments, the way individuals move through an area directly affects efficiency. While individual search strategies are fairly well understood, we still don't fully know how being in a group changes the way individuals explore. Previous studies showed that the geometry of ant exploratory trajectories depends on group density, but the reason behind this density dependence remains unclear. This study aims to bridge that gap by focusing on how cooperation influences exploratory patterns in ants. Using Argentine ants, an invasive species known for their highly cooperative foraging behavior, we examine how group size affects movement patterns during exploration. By tracking ant trajectories across different group sizes, we analyze the relative roles of chemical cues, such as pheromone trails, and physical interactions between individuals in shaping exploratory paths. Our findings not only provide insight into the mechanisms underlying collective ant behavior, but also have broader implications beyond biology. Understanding how simple interaction rules influence exploration can inform real-world applications such as search-and-rescue operations and swarm robotics. By mimicking the collective strategies used by ants, robotic systems may be able to explore environments more efficiently, improving performance in disaster response, and environmental monitoring.

 Student Researchers: Shifa Hammoudeh, Clea Chelala, Undergraduate

 Faculty Advisor: Simon Garnier

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### #332 | IS APOPTOSIS REQUIRED FOR REGENERATION IN THE CTENOPHORE MNEMIOPSIS LEIDYI?

Mnemiopsis leidyi, commonly referred to as a “comb jelly,” belongs to a lineage of invertebrate marine animals called ctenophores that can regenerate, replacing missing organs after injury. The cellular basis for the regenerative capabilities of *M. leidyi* is unknown. Two different regenerative pathways are known from other animals, only one of which requires apoptosis. Apoptosis is the highly organized process of a multicellular organism’s programmed cell death and occurs to prevent cellular dysfunction from injury. Hydra, another highly regenerative marine invertebrate, shows us that apoptosis is required for stem cell-mediated regeneration but not for tissue remodeling-driven regeneration, suggesting that apoptosis dependence varies based on strategy. This study is designed to determine whether apoptosis is required for ctenophore regeneration. Our first step is to validate assays for apoptosis detection in ctenophores. We used the “gold standard” assay for apoptosis, terminal deoxynucleotidyl transferase dUTP nick end labeling (TUNEL), which labels nicked genomic DNA that is the result of the genome cutting during apoptosis. In parallel, we used a live indicator dye that becomes fluorescent upon cleavage by a caspase enzyme (CellEvent™ Caspase-3/7), designed for use in mammalian cells. Signal indicates cleavage of a peptide sequence cleaved by caspase enzymes, a family of enzymes that act in cascade to regulate apoptosis. We used UV irradiation to induce apoptosis and surgical manipulations to induce potentially regenerative injuries. Following Hydra’s mechanisms, if *M. leidyi* use stem cells, apoptosis might be required. If *M. leidyi* does not use stem cells, apoptosis might not be required.

 Student Researchers: Magy Hanna, Jovita Joseph, Undergraduate

 Faculty Advisor: Allison Edgar

 Bioscience & Bioengineering

### #333 | EFFECTS OF CAFFEINE ON THE COLLECTIVE CIRCLING RESPONSES OF LARVAL ZEBRAFISH DANIO RERIO

Mass behavior is the rapid adoption of similar behavior by individuals within a group and occurs across many animal species, including humans. Mental states such as anxiety or stress can influence these mass behaviors and may contribute to crowd-related catastrophes like the Astroworld stampede in Houston, Texas. As a model of mass behavior, we are using larval zebrafish, which collectively circle the edges of a confined space at high densities. The purpose of this study was to determine how anxiety would impact this mass behavior. To induce anxiety, we administered caffeine, a commonly consumed stimulant, because it has been linked to anxiety-like behavior in individual zebrafish and hypothesized that caffeine would increase the frequency of collective circling responses. We first determined the optimal caffeine dose under which distinguishable physiological changes in locomotion could be observed. Preliminary data suggest that caffeinated larvae performed fewer bouts of movement compared to control larvae; however, there was no significant difference in bout counts or interbout intervals between the doses of caffeine that were tested. Thus, to assess the impact on mass behavior, we tested our highest (200 mg/L) and lowest (50 mg/L) doses against a control. Contrary to our hypothesis, we found that caffeine-exposed larvae showed a reduction in circling responses compared to control larvae, with the high-dose of caffeine drastically reducing or completely eliminating collective circling events. Future experiments will test the effects of fluoxetine, an anti-anxiety drug, on this circling response.

 Student Researcher: Bansari Mistry, Undergraduate

 Faculty Advisor: Kristen Severi

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### #334 | PREDICTIVE MODEL FOR KIRIGAMI SKIN GRAFTS TO MINIMIZE DONOR TRAUMA

Split-thickness skin grafting is a widely used treatment for chronic wounds and severe burns. In this procedure, a thin layer of healthy skin is harvested, meshed with incisions, and mechanically expanded to cover a larger wound area. Conventional meshing patterns use parallel slits, and surgeons typically rely on simplified geometric assumptions to estimate the achievable expansion ratio. These assumptions treat each slit as opening into a perfect square during stretching. However, this approach significantly overestimates the true expansion ratio because it neglects the nonlinear mechanical behavior of skin and the geometric constraints of the incision pattern. As a result, surgeons may harvest more healthy skin than necessary or fail to achieve sufficient wound coverage. In this study, we develop a predictive, mechanics-based model for skin graft expansion. Using finite element simulations, skin is modeled as a hyperelastic material to capture its nonlinear response under surgical stretching. By analyzing a representative unit of a meshed graft under plane stress conditions, we derive analytical expressions that accurately predict the expansion ratio as a function of slit opening. Simulation and experimental results demonstrate improved agreement between model predictions and observed expansion behavior. We then extend this framework to kirigami-inspired meshing patterns, which enable multidirectional expansion. Unlike conventional parallel cuts that lead to transverse shrinkage upon stretching, kirigami geometries expand in both directions when stretched, producing greater area gains. This work establishes a mechanical framework for predicting and optimizing skin graft expansion, with the goal of maximizing wound coverage while minimizing donor site trauma.

 Student Researcher: Aditya Sharma, Undergraduate

 Faculty Advisor: Farid Alisafaei

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### #335 | CRISPR-CAS9 KNOCKOUT OF ST3GAL4 GENE TO SUPPRESS TUMOR GROWTH AND IMMUNE EVASION IN GLIOBLASTOMA

This proposal aims to investigate the contribution of sialic acid and the sialyltransferase ST3GAL4 to cancer progression in glioblastoma cells. Sialyltransferases can contribute to cancer by altering the glycocalyx. The glycocalyx is a thin layer of glycoproteins and glycolipids outside the cell membrane that aids in cell-cell signaling and maintains cell integrity. However, when sialyltransferases such as ST3GAL4 are overexpressed, high amounts of sialic acid are added to glycoproteins and glycolipids, leading to cancer cell migration, tumor growth, and immune system evasion. To prevent this overexpression, the ST3GAL4 gene is knocked out using CRISPR-Cas9, a gene-editing tool. Removing the ST3GAL4 gene, which codes for the ST3GAL4 sialyltransferase protein, lowers the amount of sialic acid in the glycocalyx. This process involves designing a plasmid with a single guide RNA to target the gene, inserting this plasmid into glioblastoma cells, and verifying the gene deletion through various techniques. These steps are expected to produce glioblastoma cells with reduced sialic acid, slower tumor growth, increased immune recognition, and improved susceptibility to treatment. Glioblastoma is a highly invasive brain cancer with limited treatment options, making it critical to explore new therapeutic targets. By knocking out ST3GAL4 and reducing sialylation in the glycocalyx, this project aims to slow tumor growth, prevent cell detachment, and enhance immune system recognition. This research will improve understanding of the glycocalyx's role in cancer progression and demonstrates the potential of CRISPR-Cas9 gene editing as a therapeutic tool for targeting disease-related genes.

 Student Researcher: Bhavna Bangalore, Undergraduate

 Faculty Advisor: Alexander Buffone

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### #336 | DETECTING IMPAIRED AND COMPENSATORY MOVEMENTS OF STROKE PATIENTS FROM MOTION SENSOR DATA USING MACHINE LEARNING

Stroke is a leading cause of long-term disability, with over 795,000 cases annually in the United States. Approximately 80% of stroke survivors experience hemiparesis, significantly limiting their mobility and independence. Telerehabilitation offers a promising solution by enabling remote monitoring of motor recovery using motion sensors. However, analyzing movement data remains a challenge, often requiring advanced manual interpretation by technicians. This project develops and validates an automated motion analysis pipeline that detects impaired and compensatory movements in stroke patients using skeletal motion sensor data. A comprehensive MATLAB-based pipeline was implemented to filter, segment, and analyze x, y, and z coordinate data, extracting over 200 biomechanical features. Using motion capture datasets from healthy controls and stroke participants, multiple machine learning models were trained and evaluated using cross-validation. Preliminary results of the machine learning algorithms with 7 patients and 7 healthy participants achieved 93.9% accuracy in distinguishing healthy participants from stroke patients, 97.7% accuracy in detecting compensatory movements, and 72.2% accuracy in detecting specific movement types in healthy and stroke patients. Through further model optimization, automated movement assessment in telerehabilitation will be possible, enabling improved accessibility, streamlined clinical decision-making, and enhanced rehabilitation outcomes for stroke patients. Beyond stroke, this technology has the potential to benefit individuals with other motor impairments, making rehabilitation more efficient and widely available.

 Student Researchers: Zaid Choudhry, Hana Ighneim, Undergraduate

 Faculty Advisor: Roni Barak Ventura

 Bioscience & Bioengineering

### #337 | A JACKHAMMER SIMULATOR FOR TASK-ORIENTED TELEREHABILITATION

Construction workers experience some of the highest injury rates of any industry, with frequent exposure to high-vibration tools such as jackhammers leading to chronic musculoskeletal and nerve damage. Beyond physical impairment, injured workers often develop fear-avoidance behaviors that limit their ability to safely return to work, a problem inadequately addressed by traditional clinic-based therapy. This project proposes a novel task-specific telerehabilitation platform that enables construction workers to rehabilitate directly on-site using a safe, sensor-enabled jackhammer simulator. The system replicates the vibration, posture, and resistance of real jackhammer operation while allowing intensity to be tuned for different stages of recovery. Integrated sensors will capture grip strength, motion, and vibration tolerance to provide real-time feedback to workers and clinicians. The platform will ultimately be synchronized with a virtual reality construction environment, enabling immersive and physically grounded rehabilitation. By combining physical simulation with VR, the system addresses both biomechanical recovery and the psychological fear-avoidance cycle that hinders return to work.

 Student Researchers: Shukan Dave, Agapinan, Alfonsus R, Matthew Pinca, Undergraduate

 Faculty Advisor: Roni Barak Ventura

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### #338 | DEVELOPMENT OF A LOW-COST PRESSURE-SENSING INSOLE FOR INDUSTRIAL GAIT MONITORING

Falls, slips and trips are among the most common causes of injuries for workers in industrial environments, especially those who stand for long periods of time, perform heavy lifting, and work on unstable surfaces. Continuously monitoring workers' balance may help identify instability or fatigue-related fall risk before it occurs. The trajectory of the Center of Pressure (COP) has been established as a reliable biomechanical indicator of postural control. However, laboratory-grade force plates are expensive and impractical, and commercially available pressure insole systems are too costly for widespread industrial use.

This project focuses on the development and validation of a low-cost wearable pressure sensing insole system for estimating COP trajectories using deep learning. The insole consists of 16 force sensing resistors (FSRs) placed at key plantar locations, with outputs digitized using an MCP3008 analog-to-digital converter (ADC) and recorded at 100 Hz with a Raspberry Pi. To create supervised training data, participants wore the insoles while standing on a laboratory-grade force plate, allowing synchronization of plantar pressure signals with the true COP obtained from the force plate. Force plate data were filtered, downsampled, and temporally aligned with insole measurements prior to model training.

A hybrid deep learning model combining convolutional neural networks (CNN) and bidirectional long short-term memory (BiLSTM) networks was trained to map multichannel pressure data to two-dimensional COP trajectories. The model demonstrated improved medial-lateral COP estimation and comparable antero-posterior performance relative to a commercial insole system, supporting the feasibility of scalable, low-cost wearable balance monitoring for industrial safety applications.

 Student Researcher: Sudarshan Ganapathy, Undergraduate

 Faculty Advisor: Wei Yin

 Bioscience & Bioengineering

### #339 | SOMATOTOPIC TMS-EVOKED POTENTIAL MARKERS OF CENTRAL SENSITIZATION IN HUMAN MOTOR CORTEX

Central sensitization (CS) contributes to pain chronification through maladaptive cortical plasticity; however, its somatotopic organization within the motor cortex remains unclear. This study evaluates TMS-evoked cortical responses across hand, leg, and face representations of the primary motor cortex (M1) during acute C-fiber thermal pain using transcranial magnetic stimulation combined with electroencephalography (TMS-EEG).

Healthy participants (N=14 pilot dataset) received neuronavigated single-pulse TMS at 90% resting motor threshold during baseline and 0.2 Hz sinusoidal thermal stimulation. EEG was analyzed for TMS-evoked potentials (TEPs), Global Field Power (GFP), Local Mean Field Power (LMFP), and scalp topographies.

Thermal pain produced region-dependent (somatotopic) cortical modulation. The hand representation demonstrated significant enhancement of N100 negativity and late positive activity ( $p < 0.05$ ), accompanied by increased GFP between 50–200 ms and sustained LMFP elevation, indicating amplified large-scale and local excitability. The leg representation showed moderate N100 modulation and smaller GFP/LMFP changes. In contrast, the face representation exhibited attenuated GFP amplification and minimal LMFP modulation despite preserved TEP morphology. Topographic analyses revealed structured spatial redistribution of activation patterns, supporting organized network reconfiguration rather than uniform cortical hyperexcitability.

These findings indicate that acute nociceptive input induces region-dependent cortical plasticity within M1, with differential vulnerability across the motor homunculus. TMS-EEG-derived measures, including TEP components, GFP, LMFP, and spatial dynamics, emerge as complementary candidate biomarkers for detecting early cortical signatures of central sensitization and guiding precision neuromodulation strategies.

 Student Researchers: Marwa Ibrahim, Dr. Elisa Kallioniemi, Negar Nemdar, Ava Manafi, Undergraduate

 Faculty Advisor: Elisa Kallioniemi

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## #340 | BRIDGING HUMAN MOTION DATASETS AND MUSCULOSKELETAL SIMULATION USING AUTOMATED MOTION RETARGETING

Human motion datasets are increasingly used in robotics, biomechanics, and human machine interaction research. However, translating these datasets into musculoskeletal simulation environments remains a major technical bottleneck. Popular motion datasets such as AMASS are typically represented using SMPL-X human body models or humanoid robot kinematics, whereas biomechanical analysis platforms like OpenSim require anatomically defined joint hierarchies, coordinate frames, and motion formats. This disconnect limits the ability to perform physiological analysis, inverse kinematics, and muscle-level interpretation of modern motion data.

This project aims to develop an automated pipeline that converts retargeted human motion data into OpenSim compatible musculoskeletal models and motion files. Building upon the General Motion Retargeting (GMR) framework, which maps human motion data onto humanoid robot representations using URDF based joint definitions, this research focuses on designing a robust conversion layer that translates robot joint trajectories into OpenSim joint coordinates.

Existing workflows often require manual processing, which limits their use to smaller datasets. The pipeline in this project enables automated processing of large scale motion datasets such as AMASS, allowing for hundreds of motion sequences to be converted efficiently and accurately. The system is designed as a reusable Python based tool that can generalize across different motion datasets and musculoskeletal models, reducing the need for new motion capture experiments and enabling rapid simulation based analysis.

Ultimately, this work contributes to a reusable, AI enabled motion processing toolchain that supports interdisciplinary research in biomechanics, rehabilitation, ergonomics, and human centered robotics by expanding access to simulation ready motion data.

 Student Researcher: Saanya Jauhri, Undergraduate

 Faculty Advisor: Xianlian Zhou

 Bioscience & Bioengineering

## #341 | EXAMINING CHRONIC NEURONAL DEGENERATION FOLLOWING BLAST AND BLUNT TRAUMATIC BRAIN INJURIES

Severe and moderate traumatic brain injuries (TBI) that military personnel experience have been studied at length, but research regarding low-level repeated injuries, which service members in training and law enforcement experience, and low-level blunt injuries that athletes are regularly exposed to, has often been neglected. This study aims to examine low-level blunt TBI and repeated blast TBI and their impact on chronic neuronal degeneration. Mice will be exposed to mild fluid percussion injury, single blast and repeated blast injuries, and sacrificed at the 30 day timepoint. Microglia and activated microglia will be labeled with Iba1+CD68, and excitatory and inhibitory neurons will be marked using NeuN+VGLUT1 and NeuN+GAD65, respectively. In order to make volumetric estimations and ensure accuracy and unbiased results, stereology techniques will be used to quantify microglial activation, neuronal excitation, and inhibition by counting colocalized cells in the dentate gyrus of the hippocampus. This work will provide a baseline for identifying neuronal death pathways by pinpointing vulnerable excitatory and inhibitory neuronal populations, which will guide future targeted investigations and therapeutic treatments for mild TBI.

 Student Researcher: James John, Undergraduate

 Faculty Advisor: Bryan Pfister

 Bioscience & Bioengineering

## #342 | EFFECT OF THERANOSTIC NANODROPLET PHASE-SEPARATION ON CELL DROPLET INTERACTION

Phase separation, which is observed in the lipid raft portion of cell membranes, can be observed in biomedically engineered PFC nanodroplets. These nanodroplets have a wide array of applications such as the ability to manipulate them as ultrasound contrast agents, due to its volatile liquid core, and as carriers for drug delivery, due to its nanosize and permeability. On account of these various applications, these droplets can be utilized for theranostic, diagnostic and therapeutic, purposes. These nanodroplets were created including the fusogenic lipid, DOTAP, and cholesterol. DOTAP is required for uptake into cells, however pairing it with cholesterol creates a specific phase separation compared to without cholesterol, which could allow greater uptake efficiency. To experiment this theory, PFC nanodroplets were incubated with the MDA-MB-231 and the MCF-10A cell line to view a differential uptake. Through flow cytometry results and analysis, it was found that PFC nanodroplets with DOTAP and cholesterol had a significantly greater uptake into both cell lines, than the formulations with only DOTAP. This data can further help design ultrasound-activatable nanoparticles for enhancing target cell uptake in various cell lines.

 Student Researcher: Roma Patel, Undergraduate

 Faculty Advisor: Rajarshi Chattaraj

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## #343 | ULTRASOUND-TARGETED DELIVERY OF XENON-LOADED MICROBUBBLES FOR NEUROPROTECTION AFTER TRAUMATIC BRAIN INJURY

Traumatic brain injury (TBI) affects approximately 69 million people annually and is prevalent among athletes, military personnel, and victims of falls or vehicle accidents, leading to persistent neurological deficits. Pharmacological treatment options remain limited due to the blood-brain barrier (BBB) restricting delivery of therapeutics to injured brain tissue. Xenon gas has emerged as a promising neuroprotective agent by acting as a non-competitive antagonist at the glycine site on N-methyl-D-aspartate (NMDA) receptors, thereby reducing excitotoxicity and oxidative stress, but inhalation-based delivery is impractical due to high costs and poor dosage control. This project investigates Xenon-loaded microbubbles (XeMBs), lipid-shelled microscopic bubbles filled with Xenon, that are delivered intravenously and ruptured using clinical ultrasound near the carotid artery.

Moderate TBI is induced in a rat model utilizing the fluid percussion injury device. Animals are then randomly assigned to different treatment groups, determining whether they receive XeMB treatment or a control saline treatment. Behavioral outcomes are evaluated to assess locomotor activity, memory, and anxiety-like behavior. Brains are collected for immunohistochemical analysis of glial activation using GFAP (astrocytes) and Iba1 (microglia), with quantitative image analysis performed in ImageJ. Injured rats exhibit hyperactivity and impaired novelty recognition, while XeMB-treated rats demonstrate behavioral performance more similar to shams, indicating partial restoration of cognitive function. Glial morphology and marker expression further support a modulatory effect of XeMBs on neuroinflammatory responses after TBI. This approach effectively transitions Xenon from a gaseous anesthetic to an injectable, targeted drug delivery system that couples diagnostic imaging with mitigating TBI-induced neuropathology.

 Student Researcher: Ishaakannan Rajeshkannan, Undergraduate

 Faculty Advisor: Rajarshi Chattaraj

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### **#344 | RAPID DRUG-TO-ANTIBODY (DAR) QUANTIFICATION OF ANTIBODY CONJUGATES USING MICRODROPLET DIGESTION-MASS SPECTROMETRY METHOD**

Antibody-Drug-Conjugates (ADCs) are highly specialized biomolecules used in biotherapeutics to deliver cytotoxic drugs to cancer cells. Evaluating their safety and efficacy involves determining the average number of drug molecules attached to each antibody, known as the Drug-to-Antibody Ratio (DAR). However, current analytical and mass spectrometry-based methods require complex sample preparation and extensive data analysis. Therefore, this creates a demand for a rapid, high-throughput, and real-time approach for DAR assessment. Previously, microdroplet reactions have been shown to accelerate enzymatic reactions of intact antibodies, in which the reactions occur in a confined water droplet. In this study, microdroplet digestion was performed in a similar manner to facilitate the characterization of conjugated antibodies (NISTmAb and Cetuximab) using commercial enzymes from Genovis® (IdeS, EndoS2 and EndoF3). Conjugated antibodies were assessed using an Agilent 6545XT Q-TOF mass spectrometer with an integrated autosampler and an electron spray ionization source, Agilent Jet Stream (AJS). Within milliseconds (<250 $\mu$ s), antibody cleavage and glycan removal was achieved, simplifying the mass spectra and enhancing desired peaks for DAR determination and distribution analysis. This preliminary evaluation of ADC mimics lays the groundwork for future ADC characterization.

 Student Researcher: Juana Perez Sanchez, Undergraduate

 Faculty Advisor: Hao Chen

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### **#345 | EARLY-STAGE ENDOMETRIAL UTERINE CANCER DETECTION USING AN ELECTROCHEMICAL SENSOR THAT UTILIZES A SHEAR-ENHANCED, FLOW-THROUGH, NANOPOROUS, CAPACITIVE ELECTRODE**

Every woman deserves a fighting chance to battle endometrial uterine cancer. However, far too many women from underrepresented communities are being diagnosed at a later stage, where survival outcomes are significantly lower. Endometrial uterine cancer, often treatable if found at an early stage, continues to illustrate unusually high mortality rates in African American women due to aggressive tumor biology and delayed diagnosis. Strikingly, p53 gene abnormalities are linked to the more aggressive type of endometrial cancer, and is more commonly found in African American women. Machine learning techniques are shown to be excellent at diagnosing cancer through the analysis of data and images. An Electrochemical Sensor that utilizes a Shear-Enhanced, flow-through, nanoporous, Capacitive Electrode (ESSENCE) is proposed to integrate machine learning and enable high sensitivity and rapid early detection of endometrial uterine cancer. The proposed microfluidic platform was designed to detect cancer biomarkers such as P53 and PTEN proteins by functionalizing the capture material with the relevant antibodies. Electrochemical Impedance Spectroscopy (EIS) was used to measure the biomarker binding and find the concentration of the target analyte (cancer biomarkers) in the sample of interest. Machine learning was then applied to analyze signal patterns and enhance detection accuracy. The combination of microfluidics and machine learning has the potential to detect endometrial uterine cancer early and provide life-saving diagnostics to women who have previously been overlooked. Early diagnosis should not be a privilege, it should be a right.

 Student Researcher: Gisselle Ambrosio, Undergraduate

 Faculty Advisor: Nellone Reid

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## #346 | COMMUNITY-LEVEL EXTINCTION IN ANT PREDATORS

Ecological specialization is an essential component of biodiversity and functionality of the Earth's ecosystems. As species go extinct, some ecological roles are lost, potentially leaving ecosystems more vulnerable to collapse. Analyzing the ecologies of extinct species can identify modern species that are prone to extinction as targets for conservation efforts. On the island of Hispaniola, a rich history of fossils provides a unique window into studying extinct ant species in addition to their modern counterparts. Ants are an ideal system to study extinction as they are ubiquitous and perform many essential duties in their environments. Modern ant ecology can be observed in nature, but studying the ecology of extinct ant species presents challenges as comparisons between modern and extinct species are not always accurate indicators of ecology. As such, the morphological characteristics of fossil ants were measured and utilized to predict their ecology, revealing how extinction has shaped Hispaniola at the community level. The community largely remained stable over 16 million years, but one niche of very large generalist predators was observed to lack modern counterparts, suggesting a potential extinction risk against the largest modern species.

 Student Researcher: Luke Bitting, Undergraduate

 Faculty Advisor: Phillip Barden

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## #347 | REDUCING DIAGNOSTIC DISPARITIES IN ENDOMETRIAL CANCER USING MACHINE LEARNING AND ADVANCED BIOSENSING

Endometrial cancer incidence and mortality are rising, with women from underrepresented groups facing delayed diagnoses and disproportionately worse outcomes. These disparities are partly driven by limitations in current diagnostic methods, including imaging algorithms and biomarker detection platforms that may not generalize across diverse patient populations. This project aims to address these disparities by integrating microfluidic droplet imaging with advanced biosensing technology. Inspired by my interest in women's health research, this work examines how machine learning models can enhance current diagnostic methods that miss early signs of cancer in patients of specific demographics.

To accomplish this, tumor-associated biomarker samples are introduced into a microfluidic device that generates uniform droplets, which are imaged using brightfield microscopy on a Nikon Eclipse Ts2 microscope equipped with a Digital Sight 1000 camera. Images collected are analyzed using convolutional neural networks (CNNs) to identify patterns associated with elevated biomarker concentrations, indicating potential cancer presence, while evaluating model performance across demographic subgroups to mitigate algorithmic bias.

The framework is designed for integration with ESSENCE, a new biosensing technology that measures tumor-related biomarkers such as TP53 and PTEN via electrochemical and optical signals. Integrating imaging analysis with biomarker detection is a promising approach to developing sensitive and equitable diagnostic tools that address real-world disparities in early cancer detection.

 Student Researcher: Khushi Dengale, Undergraduate

 Faculty Advisor: Nellone Reid

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### #348 | EXPOSURE TO POLYSTYRENE NANOPLASTICS DIFFERENTIALLY IMPACTS PLACENTA DEVELOPMENT IN A SEX-SPECIFIC MANNER

Nearly 460 million tons of plastic were produced in the year 2024. The majority of plastics produced are left to degrade into smaller particles known as nanoplastics. Nanoplastics have been measured in the placenta, yet little is known about the impact of plastic particles in the placenta. The placenta is a temporary organ developed during pregnancy to support the developing fetus. For our study, we dosed pregnant CD-1 mice with either vehicle control, 50 nm or 200 nm polystyrene nanoplastic particles at 5 mg/kg/day from gestational day 8 to 15. For morphology analysis we measured the area of the layers of the placenta as they each have their own unique function. The male decidua, responsible for hormone production, decreased in the 200 nm group and borderline in the 50 nm group. We also looked into the size of the maternal and fetal blood spaces and the intrahemal barrier between them to ensure there was still proper exchange between the mother and the fetus and found the maternal blood space was significantly decreased in size and the intrahemal barrier was borderline significantly decreased for the 200 nm males. Finally, we analyzed the expression of relevant genes revealing changes in expression genes essential for hormone function, lipid metabolism, and genes required to maintain a healthy pregnancy. Our results show that the impact of plastics on placenta development is both dependent on the sex of the fetus and the size of the particle.

 Student Researcher: Allison Harbolic, Undergraduate

 Faculty Advisor: Genoa Warner

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### #349 | SOMATOTOPIC OSCILLATORY SIGNATURES OF CENTRAL SENSITIZATION IN HUMAN MOTOR CORTEX

Central sensitization (CS) is a core mechanism in pain chronification, yet objective cortical biomarkers capable of detecting early maladaptive plasticity remain limited. This study investigates oscillatory signatures of acute C-fiber thermal pain in the human primary motor cortex (M1) using transcranial magnetic stimulation combined with electroencephalography (TMS-EEG). Healthy participants (N=14; pilot dataset) received neuronavigated single-pulse TMS at 90% resting motor threshold during baseline and 0.2 Hz sinusoidal thermal stimulation. EEG was recorded with a 64-channel system and analyzed for event-related spectral perturbation (ERSP) and inter-trial coherence (ITC) within a nine-electrode left M1 region of interest. We hypothesized that thermal pain would induce frequency-specific oscillatory modulation within M1 exhibiting somatotopic organization.

Alpha (8–12 Hz) oscillations index corticothalamic inhibitory regulation, whereas beta (13–30 Hz) rhythms reflect sensorimotor integration and excitation–inhibition balance. Compared to baseline, thermal pain produced significant modulation of alpha and beta synchronization and altered phase consistency ( $p \leq 0.05$ ). Importantly, these effects varied across hand, face, and leg representations, demonstrating somatotopic specificity.

These findings challenge models of uniform cortical hyperexcitability and instead indicate spatially organized reconfiguration of corticothalamic and sensorimotor networks during early central sensitization. These oscillatory signatures provide candidate biomarkers for identifying individuals at risk for maladaptive pain plasticity and guiding precision neuromodulation strategies.

 Student Researchers: Ava Manafi, Negar Namdar, Dr. Elisa Kallioniemi, Marwa Ibrahim, Undergraduate

 Faculty Advisor: Elisa Kallioniemi

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## #350 | STRAIN DIRECTIONALITY CONTROLS NUCLEAR PORE OPENING AND YAP-MEDIATED GENE REGULATION

Cells constantly sense and respond to mechanical forces in their environment. One important regulator of this response is Yes-associated protein (YAP), a transcriptional co-activator that must enter the nucleus to activate genes involved in proliferation, migration, and tissue repair. While previous studies have shown that nuclear shape correlates with YAP localization, the underlying mechanical mechanism that controls its transport into the nucleus remains unclear. In this study, we test a fundamental idea: not only how much the nucleus is deformed, but how it is deformed, determines YAP transport. Specifically, we hypothesize that biaxial mechanical strain (stretching in two directions) promotes the opening of nuclear pores and enhances YAP entry, whereas uniaxial strain (stretching in one direction) restricts pore opening and limits transport. To test this hypothesis, we developed an integrated computational and experimental approach. Cells were cultured on engineered fiber networks with diameters ranging from 150 nm to 6600 nm. These fiber architectures were designed to generate controlled nuclear deformation states, producing either predominantly uniaxial or biaxial strain in the nuclear membrane. A theoretical model was used to predict strain directionality on the nuclear membrane, and these predictions were compared with experimental measurements of YAP nuclear localization. Our results show that biaxial nuclear strain significantly increases YAP translocation into the nucleus, while uniaxial strain suppresses it. These findings identify strain directionality as a key mechanical regulator of gene activation and suggest new opportunities to control cell behavior through engineered microenvironments, with potential applications in regenerative medicine and cancer treatment.

 Student Researchers: Parisa Priyam, Fatemah Ramezani, Undergraduate

 Faculty Advisor: Farid Alisafaei

 Bioscience & Bioengineering

## #351 | POTENTIAL IMPACTS OF COMPETITION WITH AN INVASIVE BEE ON THE EASTERN CARPENTER BEE MORPHOLOGY

Invasive species can threaten biodiversity by exploiting the ecological niches of native species. This study examines morphological changes in *Xylocopa virginica* (Eastern Carpenter Bee) before and after *Megachile sculpturalis* invasion. It is a secondary cavity-nesting bee that occupies other species' nests, with studies documenting *M. sculpturalis* invading *X. virginica* nests. Nest size is positively correlated with body size in these species, so this potential competition could influence bee morphology. We hypothesized that *Xylocopa virginica* would exhibit different average body and head sizes before versus after the invasion of *Megachile sculpturalis*. Specimens collected in the tri-state area around New York City between 1905 and 2015 were measured, with records showing *M. sculpturalis* invaded New York around 2003. Head width and intertegular distance of 100 female *Xylocopa virginica* specimens were measured using linear morphometric techniques and digital calipers. Results show an upward trend in body size and head size of *X. virginica* after the invasion of *M. sculpturalis*, although not statistically significant. This suggests that competition may not have had a strong influence during the sampled time period. Additional data extending into recent years (2015 to 2025) could clarify the effects of competitor invasion on the *X. virginica*. If the observed upward trend is significant over a longer sampling period, it may suggest that larger body and head size allow them to be better foragers and competitors for resources. Notably, these results do not align with previous studies predicting bee body size reduction as a response to climate change.

 Student Researcher: Vita Infurna, Undergraduate

 Faculty Advisor: Caroline Devan

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## #401 | UNDERSTANDING THE ROLE OF GEL LAYER PROPERTIES IN THE SWOLLEN HPMC TABLETS ON DRUG RELEASE BEHAVIOR

Hydrophilic matrix tablets based on hydroxypropyl methylcellulose (HPMC) form a viscoelastic gel layer upon hydration, affecting drug release either through diffusion or erosion-controlled mechanism. Despite advances in understanding of gel layer effect on release mechanisms, there is still room to bring mechanistic insight into predicting drug release based on the viscoelastic behavior of the gel layer coupled with polymer scaling and rheology. Rheological measurements probe the viscoelastic behavior of gel layer in hydrophilic matrix tablets but have not been linked to models for predicting drug release. Current models use many assumptions and oversimplifications to relate polymer molecular weight and polymer loading to drug release that limit their usefulness. To bridge this gap, the objective of this research is to more accurately predict the drug release within the gel layer by relating rheological properties of the gel layer to polymer scaling models for drug release. The properties of gel layer are highly sensitive to the extent of entanglement of the polymer chains and can be reflected in measurements of loss tangent,  $\tan(\delta)$ , where a transition between an entangled state with predominately solid-like behavior ( $\tan(\delta) \gg 1$ ) occurs. Overall, determining  $\tan(\delta)$  as a measure of the extent of entanglement within swollen tablets can be linked to an equivalent molecular weight ( $M_{eq}$ ) to improve polymer scaling model, resulting in more accurate prediction of drug release from HPMC tablets regardless of drug model or HPMC formulation.

 Student Researcher: Shima Baloochestanzadeh, Doctoral

 Faculty Advisor: Kathleen McEnnis

 Chemistry

## #402 | SAFETY OF CYCLOHEXANES AS PHTHALATE ALTERNATIVES

Phthalates are the most common plasticizers. Phthalates are added to polyvinyl chloride (PVC) plastics to make the plastic material flexible. However, phthalates are not covalently bonded to PVC meaning they easily leach out of products and increase human exposure. Additionally, phthalates are frequently found in personal care products that target the female consumer increasing their risk of potential exposure. Recent studies have shown the harms that these chemicals may have on our endocrine system. Phthalates are commercially used within their diester form, however, in the body they are metabolized and are formed into their more toxic metabolites known as monoesters. Companies are starting to make alternatives (cyclohexanes), but cyclohexanes have not been fully studied regarding their effects on the endocrine system. The objective of this project is to synthesize meta, para, and ortho analogs of cyclohexanes and conduct in vivo and in vitro evaluations for the diesters and metabolites respectively, and to determine the potential effects on the ovary and hormone signaling. The reaction will occur by reacting cyclohexane acids or anhydrides with different alcohols via Fischer-esterification. Cyclohexanes will be characterized via NMRs, mass spectroscopy, FTIR and elemental analysis. After that is determined female CD-1 mice are dosed with them to determine the potential toxicity through analyzing gene expression and hormone assays. Our results indicate that the diesters forms of the cyclohexanes have been synthesized and characterized. This research will help determine the effects and the mechanism and the structural activity of cyclohexane alternatives with regard to the endocrine system.

 Student Researcher: Joao Agudo, Doctoral

 Faculty Advisor: Genoa Warner

 Chemistry



### #403 | PFOS AND PFOA INTERACTION WITH ORGANIC CHROMOPHORE BOUND SERUM ALBUMIN

Perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are persistent in water bodies and are highly thermal and chemically stable, making them non-biodegradable. When bound with proteins, this can pose health risks. Several detection methods involving; chromatography, mass spectrometry, and other PFOS/PFOA detection procedures are time-consuming. Here, fluorescence spectroscopy is used to probe PFOS and PFOA by utilizing a chromophore-bound serum albumin complex based on the squaraine (SQ) dye's photophysical properties. The prepared SQ herein interacted with bovine serum albumin (BSA) which forms SQ-BSA complex and showed strong fluorescence signal. Subsequent PFOS and PFOA addition revealed a gradual fluorescence turn-on and turn-off respectively, which continued to change along these two directions up to 20  $\mu\text{M}$ . Overall, these sequentially studied tri-component systems (SQ, BSA, PFOS/PFOA) discriminative response relies on the SQ-BSA's different interacting behaviors with PFOS and PFOA. The discrimination ability of PFOS and PFOA by the SQ-BSA complex becomes ascribed by the different interacting abilities of these two harmful pollutants with BSA amongst various studies. Therefore, the result shows potential new insights towards PFAS discrimination study and offers mechanistic insight into how PFOS and PFOA may influence albumin structures.

 Student Researcher: Muhammad Aminu Auwalu, Doctoral

 Faculty Advisor: Yuanwei Zhang

 Chemistry

### #404 | CLICK CHEMISTRY-BASED DETECTION OF PHTHALATES IN MOUSE OVARIES

Phthalates are chemical additives found in plastic products to enhance their flexibility and durability. However, recent studies have shown that phthalates can disrupt key reproductive processes, potentially leading to conditions like premature ovarian failure and infertility. While the harmful effects of phthalate exposure on the ovaries are known, the mechanism of action and specific sites of localization within the ovary remain unknown. To explore this, we synthesized an alkyne-functionalized phthalate, di(non-8-yn-1-yl) phthalate, using a one-step Fischer esterification reaction. The alkyne structure on the compound enables it to be tagged with a fluorescent dye via bioorthogonal reaction and visualized in organ tissue through compact fluorescence microscopy. We conducted one-day in vivo dosing using our modified phthalate in young female CD-1 mice, followed by fluorescent labeling and image analysis. We expect that our phthalate will be detectable within the ovary. It will localize within vital ovarian structures, such as granulosa cells, theca cells, and the oocyte. This experiment will help to identify where phthalates localize in the body and which reproductive processes are affected by exposure. A deeper understanding of their mechanisms of action and localization can further the design of safer alternatives to phthalates in consumer products and provide insight into the scope and severity of their effects. Supported by NIH R00ES031150.

 Student Researchers: Leyla Bobic, Joao P. Agudo, Margaret R. Meschia,  
Hemanth Kumar Yogendra, Doctoral

 Faculty Advisor: Genoa Warner

 Chemistry



## #405 | PHOTOCAGING AND LIGHT-TRIGGERED DRUG DELIVERY

Photo-removable protecting groups, or caging groups, provide a powerful strategy to regulate the activity of bioactive molecules with precise spatial and temporal control. In this work, we designed and synthesized a symmetrical BODIPY-based oxime ester photo-uncaging group capable of releasing two carboxylic acids upon light irradiation. This system enables efficient and selective activation of otherwise inactive molecules, thereby offering potential applications in drug delivery. To demonstrate the utility of this approach, we constructed a photo-responsive drug delivery system for the controlled release of valproic acid (VPA). VPA is known to inhibit histone deacetylases (HDACs) and induce apoptosis in tumor cells. Our design allows for the double release of VPA molecules from a single BODIPY-based scaffold, improving drug loading efficiency and minimizing undesired side effects. Preliminary results show that upon light exposure, VPA is liberated in its intact form, with significant potential for targeted cancer therapy due to the high spatiotemporal precision of light activation and reduced off-target toxicity. This study highlights the promise of BODIPY-based oxime esters as versatile photo-uncaging tools and expands the application of photochemical strategies in drug delivery and chemical biology.

 Student Researcher: Xuemei Chen, Doctoral

 Faculty Advisor: Yuanwei Zhang

 Chemistry

## #406 | AGGREGATION, STABILITY, AND FATE OF REAL-WORLD NANOPLASTICS IN FRESH AND HIGH-SALINITY WATERS

Nanoplastics generated from the degradation of plastic waste are increasingly recognized as environmentally relevant colloidal contaminants in aquatic systems. Once released, nanoplastics rarely remain as isolated particles and instead undergo aggregation processes that strongly influence their transport, stability, sedimentation, and potential biological interactions. This project investigates the aggregation dynamics of nanoplastics generated from real-world plastic waste, providing environmentally realistic insight beyond studies relying on pristine synthetic nanoplastics. Nanoplastics derived from polyethylene terephthalate (PET), polystyrene (PS), and polypropylene (PP) consumer waste are produced through controlled mechanical erosion to mimic environmental fragmentation processes. Polymer identity and surface functional groups are confirmed using Raman and Fourier-transform infrared spectroscopy, while particle size distribution, morphology, and surface charge are characterized using dynamic light scattering and scanning electron microscopy. Aggregation behavior is evaluated using time-resolved measurements of hydrodynamic radius in electrolyte solutions containing monovalent and divalent cations. Systematic variation of ionic strength and ion valence enables determination of aggregation rates and critical coagulation concentrations under environmentally relevant conditions, simulating freshwater and estuarine systems where changes in water chemistry play a key role in controlling nanoplastic stability and mobility. The results provide mechanistic insight into how surface heterogeneity of real-world nanoplastics influence aggregation behavior, improving understanding of nanoplastic environmental fate and supporting more accurate predictions of transport and persistence in aquatic environments, thereby contributing to improved environmental risk assessment frameworks.

 Student Researcher: Ananda Pokhrel, Doctoral

 Faculty Advisor: Somenath Mitra

 Chemistry



## #407 | RAPID ANTIBODY STRUCTURAL CHARACTERIZATION AND QUANTIFICATION VIA MICRODROPLET TRYPSIN DIGESTION

In this work, we described a novel ultrafast and automated method for antibody structural characterization and quantification using online microdroplet trypsin digestion coupled with mass spectrometry. The microdroplet environment was generated in Jet Spray ion source which significantly accelerates enzymatic digestion, achieving efficient protein cleavage in less than 1 ms with over 90% digestion efficiency, greatly reducing sample preparation time compared with conventional in-solution digestion methods. This method also enables rapid peptide mapping with high sequence coverage and confident post-translational modifications (PTMs) identification and quantification. The absolute amount of methionine oxidation was successfully quantified by spiking the mAb sample with standard peptides for microdroplet digestion, and the deamidation was relative quantified by using the was quantified by comparing isotopic peak intensities of specific fragment ions generated in MS/MS. Moreover, by spiking the antibody with a heavy isotope-labeled antibody, our microdroplet digestion method allowed quick absolute antibody quantification, demonstrating good linearity ( $R^2 = 0.99$ ), sensitivity (LOD: 1.2 ng), and accuracy (0.6–10% quantification error). Compared with traditional bottom-up LC-MS workflows, this microdroplet digestion strategy minimizes sample preparation time, reduces artificial PTM formation, and improves analytical throughput. The automated workflow enables fast, reliable antibody characterization and quantitation, highlighting its strong potential for applications in biopharmaceutical analysis, quality control, and proteomics research.

 Student Researcher: Mengyuan Xiao, Doctoral

 Faculty Advisor: Hao Chen

 Chemistry

## #408 | ULTRAFAST MICRODROPLET DIGESTION OF ANTIBODIES WITH FC-SILENCING MUTATIONS

Novel therapeutic monoclonal antibody (mAb) modalities with mutations that silence unwanted binding to Fc-gamma receptors have resulted in many different variants in clinical trials. However, mutations could bring resistance to IdeS enzymatic cleavage into mAb subunits, limiting the antibody middle-down analysis by mass spectrometry (MS). Herein we showed, for the first time, the efficient, reproducible, and ultrafast microdroplet digestion (less than 1 ms) of mAbs carrying a series of mutations “LALA”, “LAGA” and “LFLE” (e.g., tool antibody LALA-DS, Nivolumab, Pembrolizumab, Vedolizumab, and PD-L1), by a new enzyme: FabRICATOR Xtra (Xtra). The digestion took place during the spray ionization process using an Agilent jet stream (AJS) ion source, with a digestion efficiency close to or more than 80%, leading to subunits with high ion abundances for identification and characterization. Our results also showed that an increased enzyme/antibody ratio or partial reduction of disulfide bonds increased the digestion efficiency. “One-pot” disulfide reduction and digestion in microdroplets could occur simultaneously by spraying mAb, tris(2-carboxyethyl)phosphine (TCEP), and Xtra together. Notably, for highly digestion-resistant PD-L1 antibody, the Xtra-based microdroplet digestion process was found to be 9 million times faster than in-solution digestion. Furthermore, a workflow was developed, using a script that can automatically choose a preferred enzyme (Xtra or Ides) for digestion, based on a target antibody input sequence. Our method is a fully automated microdroplet protein digestion technique that integrates flow injection (FI) and online MS analysis, providing a rapid and robust method for the structural characterization of mAbs with mutations.

 Student Researcher: Yongqing Yang, Doctoral

 Faculty Advisor: Hao Chen

 Chemistry



## #409 | ADVANCING RINSE-FREE MOLECULAR LAYER-BY-LAYER (MLBL) MEMBRANES: SCALABLE FABRICATION WITH ENHANCED FOULING RESISTANCE, SCALING RESISTANCE, AND BORON SELECTIVITY

Growing population, industrial activity, and climate change are placing increasing stress on global freshwater resources, making desalination an essential source of clean water in many regions. Reverse osmosis (RO) is the most widely used desalination technology because it efficiently removes salts using semi-permeable polymer membranes. However, the performance of current RO membranes is limited by fouling, mineral scaling, and poor removal of certain contaminants such as boron, especially under neutral pH conditions. These challenges increase energy consumption, cleaning frequency, and operating costs.

This work presents a new approach for fabricating RO membranes using a rinse-free molecular layer-by-layer (mLbL) process. By carefully controlling the amount of monomer added during membrane formation, the process eliminates the need for intermediate solvent rinsing while producing highly uniform polyamide films. The resulting membranes have an ultrathin selective layer (~20 nm), are approximately 100 times smoother than commercial membranes, and exhibit a highly cross-linked structure. As a result of this precise structural control, the membranes consistently achieve very high salt rejection (>99.6% NaCl) while maintaining stable water permeability. Importantly, they demonstrate greater than 90% boron rejection in a single pass at neutral pH, a level of performance that cannot be achieved by conventional RO membranes without pH adjustment or multiple treatment stages. In addition, the membranes carry nearly twice the surface charge of commercial membranes, which enhances hydration and electrostatic repulsion. This leads to strong resistance to organic fouling and silica scaling, with nearly complete flux recovery after simple rinsing with deionized water.

 Student Researcher: Samarpan Deb Majumder, Doctoral

 Faculty Advisor: Wen Zhang

 Chemistry

## #410 | SYNTHESIS OF PHTHALATE DIESTER TO STUDY MECHANISM OF ACTION USING CLICK-CHEMISTRY

Phthalates are synthetic chemical additives widely used in plastics, cosmetic products and food packaging materials to enhance durability and flexibility. Despite their relatively short half life, growing evidence links phthalate exposure to endocrine disruption, fertility issues and developmental abnormalities in neonates. However, the precise molecular mechanisms driving these adverse effects remain poorly understood. This study aims to elucidate the mechanism of action of phthalates by employing click chemistry-based approaches to isolate phthalate-bound DNA targets for analysis through next generation sequencing.

To attain this, a customized phthalate diester was synthesized through a one-step Fischer esterification reaction. The successful synthesis of phthalate diester was confirmed using nuclear magnetic resonance spectroscopy, mass spectrometry and elemental analysis. The terminal alkyne on the ester side chain of the synthesized phthalate compound enables biotin tagging through a bioorthogonal reaction, while the UV-activated diazirine ring facilitates covalent bond formation with target receptor proteins. CD-1 mice will be treated with the synthesized compound and ovaries, uterus and liver will be harvested and isolate DNA fragments containing the phthalate-receptor complex.

This approach will identify localization of phthalate compounds within biological systems and clarify how these harmful chemicals interact with nuclear receptors and affect downstream gene expression. Ultimately, this research will help in understanding phthalate toxicology, help in development of safer chemical alternatives and support evidence-based regulatory action to protect public health. This work is supported by NIH R00ES031150

 Student Researcher: Hemanth Kumar Yogendra, Masters

 Faculty Advisor: Genoa Warner

 Chemistry



## #411 | VISIBLE-LIGHT ACTIVATED PERSULFIDE DONORS BASED ON BODIPY PHOTOCAGE SCAFFOLD

Reactive sulfur species (RSS), particularly persulfides (RSSH), play significant roles in redox signaling and cellular regulations. However, their generation and detection remain challenging due to their high reactivity. Persulfides often undergo electrophilic and nucleophilic reactions with other RSS, or can generate reactive perthiyal radicals, complicating their monitoring in biological systems. To address challenges in studying persulfides in vivo, the development of persulfide donors has emerged as a promising strategy. There has been some advancement in this area, including the use of esterase to release persulfides in situ. However, photoactivated donors allow for the added advantage of time- and space-control of the release, as well as monitoring in real-time through non-invasive fluorescent changes.

In this study, we successfully synthesized a BODIPY-based persulfide donor that leverages the perthiocarbonate functional group and is stable in buffer. BODIPY dyes are fluorescent under visible light and have been used widely as photocages in biological systems. Conversely, to verify persulfide release, we used a poorly fluorescent trapping agent, monobromobimane (MBB), a reagent known for its ability to detect persulfide species. Upon irradiation, we monitored the release of the persulfide and its trapping by the probe via UV-vis spectroscopy and fluorescence emission measurements. We observed a decrease in donor emission accompanied by an increase in MBB-derived fluorescence. Additionally, we confirmed the formation of the bimane-persulfide adduct by LC-MS analysis, further validating the release mechanism.

This presentation will highlight our synthetic efforts toward the donor and probe, recent results, and future directions.

 Student Researcher: Dhyeyi Kakkad, Undergraduate

 Faculty Advisor: Pier Alexandre Champagne

 Chemistry

## #412 | LIGHT-TRIGGERED LYSOSOMAL PH ELEVATION USING A PHOTOBASE GENERATOR

Lysosomal pH is crucial but an under-explored topic, in which imbalance is a key factor of lysosomes rupture, dysfunction, and cell necrosis. Disruption of lysosomal pH also affects many downstream processes, such as protein degradation, proteases activities, and ions flux. Thus, modulating of lysosomal pH is gaining increasing interest as an anticancer therapeutic strategy. In this study, a BODIPY-based photobase generator BD-TMG showed lysosome targetability and was used to target lysosomes with the aim to elevate lysosomal pH in a light-guided manner. In dark, BD-TMG has low cytotoxicity, but under green LED light, it shows an exhibits high efficiency in generating a strong base, tetramethylguanidine (TMG) that can increase lysosomal pH and lead to cell death. The result demonstrated the ability of inducing pH increase elevation using green LED light and the potential ability of using BD-TMG for oxygen-independent phototherapy in cancer treatment.

 Student Researcher: Aditya Mahalingam, Undergraduate

 Faculty Advisor: Yuanwei Zhang

 Chemistry



## #413 | IMPACT OF POLYETHYLENE TEREPHTHALATE (PET) NANOPLASTICS AND PHTHALATE CO-EXPOSURE ON PLACENTAL MORPHOLOGY

Plastics are an ubiquitous part of everyday life. Due to their widespread use, plastics are produced in enormous quantities. Most are not intended for long-term use, and thus are rapidly disposed of. Its material will quickly degrade and form micro- and nano-plastics known as MNPs. Phthalates, chemicals commonly used as plasticizers to increase the flexibility and durability of plastics, were administered at doses estimated to reflect dietary exposure. Microplastics and nanoplastics can be absorbed into the human body, potentially carrying associated chemical additives. Similar to phthalates. They can enter through many different means such as ingestion, dermal exposure, inhalation, and so on. Human exposure to microplastics and nanoplastics has resulted in their detection in various tissues, including the placenta. The placenta is the main supporter of fetal development as it facilitates nutrition, blood supply, and provides immune protection. Few research has examined the effects of nanoplastics on placental structure, though their presence has become a common occurrence.

This study will investigate how exposures to polyethylene terephthalate (PET) nanoplastics and a mixture of phthalates can affect placenta morphology. To assess effects on placental structure, pregnant mice were administered nanoplastics, phthalates, or a combination through their diet, and placentas were subsequently collected for morphological analysis across different layers. By evaluating both the single and combined exposures, this research aims to understand whether co-exposures from phthalates and nanoplastics will produce dangerous effects on the placenta and fetal development. Understanding these impacts is imperative as they will directly influence fetal development and pregnancy outcomes. This work will also allow us to contribute to growing research on environmental plastic exposures and their risk to maternal and fetal health.

 Student Researcher: Valarie Maly, Undergraduate

 Faculty Advisor: Genoa Warner

 Chemistry

## #501 | FRIENDS OF A DIVIDED COURT: THE ROLE OF RELIGIOUS AMICUS BRIEFS IN DOBBS V. JACKSON

The U.S. Supreme Court's 2022 decision in *Dobbs v. Jackson Women's Health Organization* was a watershed moment in the history of American abortion law. In a 6-3 decision, the Court overturned the constitutional right to abortion it first established in its 1973 *Roe v. Wade* decision. As hailed by its supporters as it was reviled by its detractors, *Dobbs* has not settled the debate over abortion. The profound divisiveness surrounding abortion mirrors the deep moral and religious differences that exist among the American populace. This project focuses on the role of religiously motivated amicus briefs in *Dobbs*. The fifty-two amicus briefs filed by religiously motivated organizations and/or individuals were analyzed by political stance and religious affiliation. The data shows substantial similarity between the legal arguments raised in the religious amicus briefs supporting the overturning of *Roe* and the reasoning of the Court's majority opinion. In analyzing *Dobbs* and its amicus briefs, we therefore argue that the relationship between religion and law in the U.S. is more complex than can be explained by a simple "separation of church and state" framing. Working within a legal system that privileges secular reasoning over religious arguments, religiously motivated interests in *Dobbs* strategically translated their moral positions into secular constitutional arguments to engender legitimacy for their policy goals. More broadly, we argue that American secularism fosters a type of disingenuity in public life, where religious actors must utilize a secular vocabulary to justify the policy goals of their religiously originated worldview.

 Student Researcher: Omar Al-Zaman, Undergraduate


 Faculty Advisor: Stephen Pemberton

 History/Law






## #601 | SONAR DETECTION OF MARINE MINES FOR SAFER SEAS

Detecting and identifying objects buried in marine sediment, such as mines, is a challenging task, particularly in complex underwater environments and when measurements are noisy. In this work, we develop advanced sonar methods that study how sound waves propagate through marine environments and scatter off hidden objects, allowing us to reconstruct their location and shape. By carefully modeling the interaction between sound waves and sediment, the method remains stable and accurate even when measurements are incomplete or partially obscured. Numerical simulations demonstrate that this is a reliable tool for safe detection and monitoring in marine environments.

 Student Researcher: Patrick Grice, Doctoral  
 Faculty Advisor: Zoi-Heleni Michalopoulou  
 Mathematics

## #602 | A MINIMAL MODEL FOR THE DYNAMICS OF REM SLEEP WITH ATONIA

One of the characteristics of REM sleep is atonia, or muscle paralysis due to the inhibition of motoneurons in the spinal cord. A role of atonia is to prevent one from acting out dreams during REM sleep, which could cause inadvertent harm to the individual or those around them. REM active neurons, which are part of the sleep-wake circuitry, project via two pathways to the spinal cord motoneurons which control atonia. Damage to the subcoeruleus nucleus (SubC) or ventral medial medulla (VMM), which are key elements of these pathways, may result in an individual experiencing REM sleep without atonia. We construct a firing rate model that combines the sleep-wake cycle and atonia pathways to discern the roles of vSLD and VMM on network dynamics. By functionally disabling key pathways in the atonia circuit, using phase plane analysis and numerical simulations, we suggest various explanations that may underlie REM sleep without atonia.

 Student Researcher: Elizabeth Tootchen, Doctoral  
 Faculty Advisor: Amitabha Bose  
 Mathematics

## #603 | THE ROLE OF CALCIUM BUFFERS IN SHORT-TERM SYNAPTIC DYNAMICS

Information transmission in the central and peripheral nervous systems relies on synaptic neurotransmitter release, which is triggered by calcium influx following membrane depolarization. However, release efficiency is not constant: it changes over short time scales in a phenomenon known as short-term synaptic plasticity. An increase in synaptic strength is termed short-term facilitation, whereas a decrease is called synaptic depression. Both processes strongly shape the dynamics of neuronal circuits.

Because neurotransmitter release is calcium-dependent, it is profoundly influenced by calcium-binding molecules (calcium buffers) that regulate the spatiotemporal dynamics of intracellular calcium. In particular, previous studies have shown that buffer depletion can underlie facilitation at certain mammalian central synapses.

Here, we present results of computational modeling to investigate more systematically how calcium buffers shape synaptic dynamics, focusing on buffers with multiple calcium-binding sites. Although such buffers are widely expressed in the central nervous system, their impact on synaptic plasticity has not been fully explored. We demonstrate that these complex buffering reactions can promote synaptic depression and can also generate richer dynamic behaviors, including transitions between facilitation and depression. Our results provide a more comprehensive understanding of how calcium buffering regulates synaptic information transmission and other fundamental calcium-dependent cellular processes.

 Student Researcher: Andrew White, Doctoral  
 Faculty Advisor: Victor Matveev  
 Mathematics



## #604 | LEAPFROGGING MOTION IN MULTI-VORTEX SYSTEMS

Since 1980, hurricanes have caused over \$1.5 trillion in damage and taken thousands of lives. Predicting how these massive rotating storms will move remains a major scientific challenge. Their motion depends on complex rotating structures within the atmosphere that cannot be directly seen. Vortex dynamics, the mathematical framework that describes how rotating fluid structures move and interact, provides tools for understanding and improving these predictions.

My research studies a striking vortex behavior called leapfrogging, where two pairs of vortices repeatedly pass through each other in a regular, alternating motion. This motion can appear stable, but small changes in system parameters can cause it to become unstable and transition into more complex behavior. I use mathematical models and computer simulations to track vortex motion and study these transitions, called bifurcations. These methods allow me to identify when stable motion persists and when it begins to break down.

This research improves understanding of how stability and instability arise in rotating fluid systems. The results help strengthen mathematical tools used to study real-world vortex phenomena, including atmospheric flows such as hurricanes. A better understanding of vortex dynamics improves our ability to analyze and predict rotating fluid motion, with potential benefits for safety, engineering, and environmental forecasting.

 Student Researcher: Nan Zhou, Doctoral

 Faculty Advisor: Roy Goodman

 Mathematics

## #605 | ENERGY-BASED STABILITY ANALYSIS OF TWO-LAYER VISCOELASTIC FLOWS WITH CHEBYSHEV SPECTRAL METHODS

In this research, we investigate the effect of stabilizing and destabilizing parameters in a two-layer Poiseuille flow with Newtonian and viscoelastic fluids. The Oldroyd-B model is considered for the governing viscoelastic stress equations. There are many parameters, including Reynolds number, Froude number, surface tension, Weissenberg number, thickness ratio, viscosity ratio, density ratio, and wavenumber, that can control the instability of the multilayer flows. The Chebyshev Spectral Collocation (CSC) method and the energy-budget analysis are applied to estimate the wave evolution at the interface. We further explore the effect of dominant components in kinetic energy, such as shear production, viscous dissipation, interfacial work, and elastic stress work, to explain the modification of the perturbation structure. The velocity distributions and stress tensor components profiles are also presented to highlight the instability reasons of complex fluid systems.

 Student Researcher: Nastaran Rezaei, Doctoral

 Faculty Advisor: Shahriar Afkhami

 Mathematics



## #606 | ENUMERATING ROOTED BINARY PHYLOGENETIC FORESTS

Mathematical phylogenists are interested in developing and analyzing methods for inferring past species relationships based on data from current species. The (network multispecies) coalescent model is one of the most realistic mathematical models for evolution of genes, but the computing probabilities generated under it is notoriously tedious and error-prone. While an algorithm does exist to symbolically compute some types of probabilities generated under the coalescent, it is not general enough for all current research uses of the model. A fully-generalized version would need to compute probabilities of observing particular rooted binary phylogenetic forests at any stage of the backwards-in-time coalescent Markov process. While rooted binary phylogenetic forests as combinatorial objects can be recursively counted for each number of leaves, accounting for them in a reasonable way in a code implementation would require an efficient algorithm to enumerate each rooted binary phylogenetic forest on any leaf number. This work presents a new direct proof of a previously-known recursive formula for counting rooted binary phylogenetic forests, and uses the constructions in that proof to build a recursively-defined enumeration.

 Student Researcher: Bryan Currie, Doctoral

 Faculty Advisor: Kristina Wicke

 Mathematics

## #607 | LONG-TERM NEUROMODULATORY CONTROL OF NEURAL ACTIVITY

Neuromodulators are chemical messengers in the brain that regulate neuronal excitability and communication between nerve cells and their target tissues by altering neuronal excitability and synaptic activity. Understanding the effects of neuromodulators is important because many neuronal functions depend on them. When these chemicals are imbalanced, they can contribute to conditions such as depression, anxiety, Parkinson's disease etc. Neuromodulatory inputs are chemical signals that modify neuronal excitability without directly triggering immediate neural firing. Experiments done in stomatogastric nervous system in the crab *Cancer borealis* tell how neuromodulators influence neural activity and behavior. Based on that, we hypothesize that neuromodulators constrain the parameters that determine stability and robustness of neuronal activity. These parameters correspond to the maximal conductance values of ionic currents representing maximum electrical conductance of ion channels when they are fully open. The set of all maximal conductance values defines a multidimensional parameter space. We propose that when neuromodulators are removed, these constraints relax, expanding parameter space and enabling neurons to find new combinations of conductance values that restore functional activity. We have tested this hypothesis on conductance based Hodgkin–Huxley–type model where we vary conductances, analyze resulting voltage simulations and characterize how neuronal activity patterns change across the parameter space. This allows us to map which combinations of conductance produce stable and functional behavior and we explore different activity regions in the presence and absence of neuromodulatory current. We plan to determine which types of neurons are capable of exhibiting parameter space expansion.

 Student Researcher: Tamanna Tamanna, Doctoral

 Faculty Advisor: Jorge Golowasch

 Mathematics



## #608 | ROBUSTNESS OF PERSISTENT HOMOLOGY WHEN NOISING AND DENOISING 3D IMAGES

Porous media are ubiquitous in nature and industry, arising in a multitude of processes including environmental cleanup, oil recovery, and CO<sub>2</sub> storage. Understanding and optimizing such processes, which typically involve flow through porous media, requires characterizing the complex internal pore structure of these materials. Techniques from Topological Data Analysis, especially persistent homology, are very helpful for this task. However, when working with real-world data—specifically 3D images of porous media—we face significant computational challenges because of the complexity of the datasets and the presence of experimental noise, which can obscure key topological features and increase computational costs.

We propose to denoise such images using Gaussian convolution, with the goal of smoothing the data and reducing noise, while preserving true topological features. We demonstrate the method using simulated image datasets, to which we add noise to mimic real experimental data, then denoise. To assess the effectiveness of our method, we use several topological measures to compare the original and denoised datasets. Finally, we discuss the optimal denoising approach that makes these measures closest to the original, noise-free data.

 Student Researchers: Aakash Karlekar, Ebru Dagdelen, Undergraduate

 Faculty Advisor: Jonathan Jaquette

 Mathematics

## #609 | MULTIPLE MECHANISMS OF RESONANCE IN EXCITATORY-INHIBITORY SPIKING NEURAL NETWORKS

Rhythmic activity is a fundamental feature of neural systems, where oscillations are observed across multiple spatial and temporal scales and contribute to coordination and information processing. When neural circuits are driven by periodic input, their responses are often frequency-dependent rather than uniform across frequencies. One manifestation of such frequency selectivity is resonance, in which network responses are selectively amplified at specific input frequencies. While resonance has been studied extensively across theoretical models, most work has focused on subthreshold single-neuron dynamics and on characterizing the conditions under which resonance appears, rather than systematically identifying the mechanisms that generate it. Comparatively fewer studies examine resonance at the level of spiking network dynamics.

This project investigates whether resonance in excitatory-inhibitory spiking networks arises from multiple distinct dynamical processes. To address this question, we implement a recurrent network of leaky integrate-and-fire (LIF) neurons composed of interacting excitatory and inhibitory populations. The network receives stochastic background noise and a sinusoidal oscillatory drive with systematically varied frequency.

Our results indicate at least two qualitatively distinct resonance regimes. The first emerges from an interaction between stochastic fluctuations and periodic input, where alignment between noise-driven timescales and oscillatory frequency produces enhanced responses in the excitatory population that are subsequently inherited at the network level. The second mechanism depends on recurrent inhibitory feedback, which introduces frequency-dependent amplification that disappears when inhibitory-to-excitatory connections are removed. These findings suggest that resonance in spiking networks may result from multiple independent mechanisms that are not fully captured by simplified one-dimensional rate models.

 Student Researcher: Pau Mendiara Monge, Undergraduate

 Faculty Advisor: Horacio Rotstein

 Mathematics



## #701 | 3D RADIATIVE MHD MODELING OF PARTICLE BEAM HEATING OF THE SOLAR ATMOSPHERE

While solar flares are primarily associated with enhanced ultraviolet and X-ray emission, a subset of flares exhibit significant continuum brightening in visible light and are classified as white-light flares (WLFs). Despite extensive observational and modeling efforts, the physical mechanisms responsible for the compact, short-lived photospheric brightenings in WLF kernels observed during the impulsive phase of solar flares remain uncertain. Thick-target electron-beam models typically deposit energy in the upper chromosphere, and their ability to reproduce the magnitude and spatial localization of photospheric continuum enhancements observed in white-light flare kernels remains an open question. To investigate the role of realistic atmospheric structuring and multidimensional transport in flare energy deposition, we perform three-dimensional radiative MHD simulations of electron-beam heating using the StellarBox code for beam fluxes of  $10^{12} \text{ erg s}^{-1} \text{ cm}^{-2}$  and low-energy cutoffs of 10–25 keV. We then compute Fe I 6173 Å Stokes profiles using the RH 1.5D radiative transfer code for direct comparison with Helioseismic and Magnetic Imager (HMI) observations. The simulations produce strong upper-chromospheric heating, multiple shock fronts, and continuum enhancements up to a factor of 2.5 relative to pre-flare levels, comparable to continuum enhancements observed during strong X-class white-light flares. Comparison with one-dimensional RADYN simulations highlights the influence of fine-scale structuring on flare dynamics and continuum emission that arises in three-dimensional geometry.

 Student Researcher: Samuel Granovsky, Doctoral

 Faculty Advisor: Alexander Kosovichev

 Physics

## #702 | ANALYSIS OF SOLAR MAGNETOACOUSTIC WAVES IN ACTIVE REGIONS WITH HIGH-ENERGY SOLAR FLARES

The existence of magnetoacoustic waves in the solar atmosphere and sunspots is well established. However, while extensive work has been done in deciphering these waves in sunspots possessing a basic unipolar or bipolar magnetic field, a full scale analysis of these waves in sunspots with more complex magnetic field structures has not been attempted. Our approach to studying these regions is to utilize similar methods from previous studies, which look at simpler sunspot structures. This involves the use of the line-of-sight (LOS) Doppler shift of the 6173 Angstrom absorption line and the LOS magnetic field data from the Helioseismic and Magnetic Imager aboard the Solar Dynamics Observatory. We elect to analyze two solar active regions which feature several high energy flares and sunspots with complex magnetic field structures. We observed a significant increase in magnetoacoustic waves specifically in between opposite-polarity magnetic field regions present within the sunspot. This increase is present in frequencies ranging from 0-1 and 6-11 millihertz (mHz); the former can be explained by the long observation period (about 20 min) of the waves, but the latter result suggests that the increase in waves may be a consequence of the interaction with the strong magnetic field which is oriented perpendicular to the satellite's line of sight. Thus, we analyze the temporal and spatial variations of these waves during the emergence and evolution of these two sunspots.

 Student Researcher: Arman Manookian, Doctoral

 Faculty Advisor: Alexander Kosovichev

 Physics



## #703 | STRUCTURED MAGNETIC FIELDS IN THE SOLAR WIND AND THEIR IMPACT ON EARTH'S SPACE ENVIRONMENT

The Sun constantly releases a stream of charged particles known as the solar wind, which carries magnetic fields toward Earth and shapes Earth's space environment. Among the magnetic structures embedded in this flow are small-scale magnetic flux ropes (SMFRs), coherent bundles of twisted magnetic fields that frequently pass Earth but remain insufficiently understood. Preliminary statistical analysis of more than 28,000 SMFR events observed near Earth indicates that their magnetic strength and flux content vary with the solar cycle. However, their occurrence rate remains relatively stable, and they are found ubiquitously throughout the near-Earth solar wind. In addition, most events are not associated with strong pressure pulses, suggesting that their potential impact may arise primarily from their internal magnetic structure rather than from external forcing. Building on this interpretation, this project will investigate how the internal magnetic configuration of SMFRs governs energy transfer from the solar wind into Earth's space environment. By integrating large-scale statistical characterization with coordinated observations of solar wind magnetic fields and the high-latitude ionosphere—a region of Earth's upper atmosphere where solar wind energy enters the geospace system – the research will identify the physical mechanisms linking structured solar wind magnetic fields to organized geospace variability. This work aims to advance understanding of persistent magnetic drivers of Sun–Earth interactions and to refine current models of space weather by incorporating the role of structured magnetic fields.

 Student Researcher: Youra Shin, Doctoral

 Faculty Advisor: Hyomin Kim

 Physics

## #704 | EVOLUTION OF GLOBAL MAGNETIC HELICITY IN SOLAR CYCLES 24 AND 25

The Sun undergoes an 11-year cycle in which its solar activity rises and falls. The solar cycle is driven by dynamo processes in the Sun, which generate and sustain the Sun's magnetic field. An important parameter of this process is magnetic helicity, which quantifies how twisted a magnetic field is. Magnetic helicity is generally conserved over the solar cycle and follows the hemispheric helicity rule (HHR), which states that it is negative in the northern hemisphere and positive in the southern hemisphere. Using synoptic vector magnetograms generated by the Helioseismic and Magnetic Imager (HMI) on the NASA mission “Solar Dynamics Observatory” for the last two solar cycles (2010–2025), we calculate the magnetic vector potential and magnetic helicity density for each solar rotation using spherical harmonic decomposition. The resulting reconstructed magnetic field and vector potential components, and the magnetic helicity density maps are longitudinally averaged over time to create time-latitude diagrams. The results observationally confirm the HHR of the global Sun's magnetic helicity over the solar cycle. We also compare the evolution of magnetic helicity density with a nonlinear, data-driven solar dynamo model and find that they agree qualitatively. These magnetic helicity maps can also be used to compare results with those from other dynamo models, improve the models, and potentially develop physics-based approaches for long-term prediction of solar magnetic activity.

 Student Researcher: Hannah Suresh, Doctoral

 Faculty Advisor: Alexander Kosovichev

 Physics

## #705 | PLASMA INSTABILITY DURING ENERGETIC PARTICLE INJECTIONS IN EARTH'S MAGNETOSPHERE

Energetic particle injections in Earth's magnetosphere are key drivers of near-Earth space plasma environment dynamics and space weather activity. During these events, bursts of high-energy protons are transported toward Earth, changing local plasma conditions. Under certain circumstances, these changes can trigger electromagnetic ion cyclotron (EMIC) waves. These waves interact with energetic particles, scattering them into Earth's atmosphere and altering radiation belt populations. Such processes can influence satellites, communication systems, and navigation technologies like GPS.

Despite their importance, the plasma conditions that determine when particle injections generate EMIC waves are not fully understood. In this study, I investigate how changes in proton energy distributions and temperature anisotropy affect plasma stability. Using coordinated observations from satellite missions, I calculate key physical parameters, including plasma beta and anisotropy and wave growth rate.

By identifying when observed plasma conditions exceed predicted theoretical thresholds, I determine the circumstances under which wave growth becomes possible. This research strengthens the connection between theoretical plasma physics and direct space-based observations. Improving our understanding of these instability processes contributes to more accurate models of space weather and enhances our ability to assess risks to modern technological systems operating in near-Earth space.

 Student Researcher: Homa Yazdi Karimi, Doctoral

 Faculty Advisor: Hyomin Kim

 Physics

## #706 | MAGNETOHYDRODYNAMIC INSTABILITIES IN THE BREAKOUT MODEL OF CORONAL MASS EJECTIONS

Coronal mass ejections (CMEs) are energetic plasma eruptions driven by the rapid release of magnetic energy in the solar corona. Although magnetic reconnection is widely accepted as a key mechanism underlying CME initiation, the physical processes that trigger reconnection remain poorly understood. In particular, the role of magnetohydrodynamic (MHD) instabilities in driving reconnection has not been fully explored within models that are known to agree with solar observations.

This project investigates the interaction between MHD instabilities and magnetic reconnection in the Breakout Model of coronal mass ejections. Using high-resolution, three-dimensional MHD simulations, I model the solar corona as a magnetized fluid evolving from empirically motivated magnetic field configurations. Initial magnetic fields are constructed through numerical extrapolation of photospheric boundary conditions, after which the system is evolved using a parallelized MHD solver on high-performance computing resources.

The simulations reproduce key observational and theoretical indicators of CME dynamics, including energy release, velocity profiles, magnetic field restructuring, and current density evolution. Preliminary results indicate that when MHD instabilities are properly resolved, magnetic reconnection emerges naturally and leads to eruption dynamics consistent with observations. Ongoing parameter studies aim to determine whether these instabilities are a necessary and sufficient condition for reconnection and eruption within the Breakout Model.

This research provides new insight into the physical mechanisms underlying solar eruptions and contributes to improved theoretical understanding of plasma instabilities, reconnection, and large-scale eruptive phenomena relevant to space weather and astrophysical plasmas.

 Student Researcher: Jaiman Parekh, Undergraduate

 Faculty Advisor: Satoshi Inoue

 Physics



## #707 | SOLAR CYCLE CHANGES IN THE SUN'S THERMODYNAMIC STRUCTURE

Despite extensive modeling, the effect of subsurface magnetic fields on the Sun's interior thermodynamic structure is relatively unexplored. To fill in this knowledge gap, helioseismic data were used to visualize long-term variations in subsurface solar properties throughout the 11-year solar cycle. Near-full disk maps of sound-speed perturbations from 0-21 Mm deep are captured by the Helioseismic Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO) satellite and stored on Stanford's Joint Science Operations Center (JSOC). These disk maps were used to construct synoptic maps and then butterfly diagrams, which represent the migration of sunspots from high latitudes toward the equator during the solar cycle. Additionally, these butterfly diagrams were converted to units of temperature differences, overlaid with magnetic field diagrams, and compared to plots of average solar irradiance. The resulting diagrams showed increases in temperature directly below the sunspots and areas of decreased temperature surrounding the sunspots that persisted into the minimum. These results suggest how subsurface magnetic fields affect the interior thermodynamics of the Sun. Comparisons with irradiance revealed trends in temperature difference that can start inphase with irradiance and transition to antiphase at greater depths, but there were conflicting results depending on how the data was originally processed. However, the findings are still indicative of a relationship between subsurface temperature and surface irradiance.

 Student Researcher: Kyle Villamayor, Undergraduate

 Faculty Advisor: Alexander Kosovichev

 Physics

## #708 | RETHINKING GEOSCIENCE EDUCATION THROUGH ONLINE COMMUNITIES

Geoscience education increasingly occurs within digital spaces where environmental, technological, and societal themes converge. Geoscience is crucial for addressing sustainability challenges related to climate change, natural resources management, and natural hazards. While traditional pedagogical models emphasize classroom-based instruction and using Geographic Information System (GIS) as the primary tool and framework, a parallel ecosystem of community-driven learning has emerged on social media platforms. This study examines geoscience communities on Reddit, where students, educators, and professionals engage in knowledge exchange, experience sharing, and mutual support beyond institutional boundaries.

We have developed a mixed-methods research pipeline which combines social media data extraction with natural language processing (NLP) techniques to investigate the educational patterns and academic engagement for geoscience careers, realizations of career expectations, and the impact of the knowledge sharing community (KSC) on the geoscience workforce and higher education. Using Reddit's API (PRAW), we collected 15370 posts from 40 geoscience-focused subreddits, including geology careers, geoscience, environmental science and GIS. Our dataset involved 24 unique subreddit combinations and contributions from a wide range of users. We applied topic modeling using spaCy and NLTK libraries to uncover thematic structures in discussions. Sentiment analysis and pattern recognition were used to examine emotional tone and identify recurring concerns such as GIS tool accessibility, fieldwork challenges, academic credentials, and career transitions.

Results demonstrate that Reddit operates as a decentralized learning environment where users actively seek mentorship, discuss academic pathways, and exchange practical advice regarding geoscience skills and career development. Unlike other platforms that emphasize brevity, Reddit's threaded, long-form discussion format enables nuanced, collaborative exploration of geoscientific topics. This peer-to-peer knowledge sharing model both supplements formal instruction and creates inclusive pathways for broader geoscience education participation.

Our findings highlight the significant yet underutilized potential of social media platforms for science communication, outreach, community building and to inform needs for transformative change in university geoscience curricula. We advocate for increased academic recognition and strategic engagement with these virtual communities to bridge gaps between formal education and practical geoscience experiences. By integrating geospatial research methodologies with digital ethnography and NLP-driven analysis, this work contributes to evolving discussions on democratizing STEM education through digital engagement strategies.

 Student Researcher: Shreyal Sharma, Undergraduate

 Faculty Advisor: Laramie Potts

 Physics



## #801 | LEARNING NONLINEAR TEST ASSETS DYNAMIC UNSUPERVISED CLUSTERING OF FIRM CHARACTERISTICS

This project develops a dynamic, unsupervised framework to construct nonlinear test assets from high-dimensional firm characteristics for empirical asset-pricing evaluation. Traditional portfolio sorts are transparent but scale poorly as the characteristic set grows: multi-way sorts fragment the cross-section, generate sparse portfolios, and struggle to represent nonlinear interactions across attributes. In contrast, many machine-learning approaches can improve prediction, but their representations are often difficult to interpret as tradable test assets and may be unstable over time. The proposed method clusters firms each month in the joint characteristic space and forms investable cluster portfolios (equal- or value-weighted) based on membership. To ensure temporal coherence and economic interpretability, the approach regularizes the evolution of cluster definitions by encouraging cluster centroids to move smoothly over time, which can be interpreted as a Gaussian random-walk prior or a quadratic penalty on month-to-month centroid drift. This design mitigates the cluster-alignment problem of naive month-by-month clustering, where labels can swap discontinuously and undermine portfolio meaning. The resulting cluster portfolios provide a sieve-like approximation to characteristic-based pricing: as the number of clusters increases, the partition becomes more expressive and can capture higher-order interactions without relying on axis-aligned bins. Empirical analyses assess (i) out-of-sample return dispersion across clusters, including monotone gradients, high-minus-low spreads, and risk-adjusted performance, (ii) whether cluster returns are spanned by standard benchmark factor models (CAPM, Fama-French variants, momentum, liquidity, and latent-factor models), and (iii) interpretability through characteristic profiles and economically meaningful dimensions such as size, value, profitability, investment, risk, and trading frictions. Overall, the framework aims to deliver stable, transparent, and scalable test assets for high-dimensional asset-pricing research.

 Student Researcher: Bhaskar Goswami, Doctoral

 Faculty Advisor: Ajim Uddin

 Data Science & Management

## #802 | AUTOMATED DETECTION OF NON-COMPLIANT AND MANIPULATIVE COOKIE BANNERS ON THE WEB

As governments pass privacy regulations requiring user consent before personal data can be collected, businesses that operate on the Web have responded with non-compliant and deceptively designed consent interfaces (i.e., cookie banners) to protect revenue streams stemming from the collection of visitors' personal data. Although the prevalence of these responses is unclear, they persist in part because regulators lack sufficient resources for large-scale manual enforcement. This research addresses these gaps by developing automated systems to detect non-compliant and manipulative websites using web crawling and computer vision technologies. First, a rule-based crawler is developed to visit websites, simulate a user opting-out of data collection, and collect cookies and HTTP requests to determine how often websites ignore the user's consent election. A second system is developed to screenshot a website's cookie banner for input to a salient object detection model, which determines if the cookie banner contains aesthetic manipulation (i.e., design choices made to nudge users' attention towards the opt-in button). These systems are deployed to measure the prevalence of websites engaging in these practices. While only 2.2% of websites misrepresent users' choices (i.e., claim the user opted-in), 72.8% of the remaining websites exploit regulatory loopholes to process personal data anyway. Furthermore, 38% of websites employ aesthetic manipulation. In the future, the systems developed here can support regulators in detecting bad actors and enhancing privacy on the Web, while the findings may inform the development of future privacy regulations and help close existing loopholes.

 Student Researcher: Riley Grossman, Doctoral

 Faculty Advisor: Yi Chen

 Data Science & Management



## #803 | TEAM SIGNALS VS. ECOSYSTEM SIGNALS: FOUNDING TEAM EXPERIENCE HETEROGENEITY AND CAPITAL ACCESS IN CLEAN ENERGY STARTUP INNOVATION

Clean energy startups are central to addressing climate change and advancing sustainable economic growth, yet many fail to scale due to difficulties in securing early-stage capital. This study examines how Founding Team Experience heterogeneity influences innovation outcomes through access to capital, and how regional ecosystem conditions shape this process.

Using a multi-source panel of 165 US clean energy startups, we test a moderated mediation framework linking founding team experience heterogeneity, access to capital and innovation output. Founding Team Experience heterogeneity is measured using a weighted Blau index, access to capital through a composite Access to Capital Index, and ecosystem knowledge capacity as a state-level Knowledge Development and Diffusion Index.

Results suggest that Founding Team Experience heterogeneity does not directly increase innovation but enhances it indirectly by improving access to capital. Ventures with more functionally diverse founding teams experience lower capital friction, and access to capital has a strong positive effect on innovation output. However, this pathway is contingent on the ecosystem environment. In high-knowledge capacity ecosystems, the effect loses statistical significance, indicating a substitution effect between internal team signals and external ecosystem validation mechanisms.

These findings suggest that firms operating in low knowledge capacity ecosystems should pay greater attention to Founding Team Experience heterogeneity to improve capital access for innovation. The importance of this diversity may be less relevant in knowledge-rich ecosystems. The study highlights how internal team composition and external ecosystem conditions jointly shape the commercialization of clean energy technologies, offering important implications for entrepreneurs, investors and policymakers.

 Student Researcher: Karthik Piedy, Doctoral

 Faculty Advisor: Xi Zhang

 Data Science & Management

## #804 | THE DIMENSIONALITY PARADOX IN SOLAR FLARE CLASSIFICATION

Identifying severe X-class solar flares is critical for mitigating space weather disruptions to near-Earth infrastructure. However, operational monitoring is challenged by the extreme class imbalance, where minor flares outnumber major eruptions. Furthermore, while machine learning architectures are deployed to capture the non-linear magnetic properties of Active Regions, the optimal dimensionality of these feature spaces for rare-event detection remains underexplored. We address this by performing multiclass classification using features extracted at the flare onset ( $T = 0$ ), enabling direct assessment of active region magnetic morphology at the moment of eruption. To establish a robust benchmark, we evaluated eight standalone algorithms and several soft-voting ensembles. Utilizing SDO/HMI data (2010–2016) and a Stratified Grouped 10-Fold Cross-Validation strategy to prevent data leakage, we evaluated model performance on a 13-parameter SHARP dataset versus a 25-parameter dataset. Our findings reveal a dimensionality tradeoff in extreme-event classification: while the expanded 25-feature space improved overall ensemble robustness, it degraded diagnostic skill for rare events. Standalone linear models better isolated X-class flares, with the Support Vector Classifier trained on the 13-feature dataset achieving the highest minority-class metrics (Balanced Accuracy: 0.641; True Skill Statistic: 0.282). Expanding to 25 features introduced orthogonal physical variance that distorted the SVC's linear decision boundaries, reducing its X-class TSS to 0.197. Furthermore, aggregating these linear signals with tree-based models via ensembles reduced minority-class sensitivity. Ultimately, adding complex physical parameters does not universally improve extreme-event detection. Reliable classification requires parsimonious feature spaces paired with algorithms suited to isolate rare events within imbalanced datasets.

 Student Researcher: Mikhail Nauth, Doctoral

 Faculty Advisor: Shahriar Afkhami

 Data Science & Management



## #805 | EVALUATING THE IMPACT OF NEW JERSEY'S ERPO LAW ON FIREARM HOMICIDE RATES IN FIVE CITIES

Firearm violence is a serious public health concern in New Jersey, where someone was killed by a firearm approximately every 20 hours in 2023. Firearm violence is highly concentrated in five cities: Camden, Jersey City, Newark, Paterson, and Trenton. These cities represent only 10% of the state's population but account for roughly 62% of all fatal and nonfatal shootings, underscoring the need for effective prevention strategies. In response to rising gun violence, New Jersey implemented the Extreme Risk Protection Order (ERPO) law in September 2019, allowing the temporary removal of firearms from individuals deemed at high risk of harming themselves or others. Although ERPOs are intended to prevent firearm-related harms, evidence of their effectiveness in doing so remains limited. It is plausible that the impact of ERPOs varies across cities due to differences in firearm violence burden and implementation practices. Herein, we use the Augmented Synthetic Control Method to evaluate whether ERPO implementation led to measurable reductions in firearm homicides statewide and within the five aforementioned cities.

 Student Researcher: Aayush Chitransh, Doctoral

 Faculty Advisor: Roni Barak Ventura

 Data Science & Management

## #806 | WHEN COMMERCIALIZATION VIABILITY ALONE IS NOT ENOUGH: UNDERSTANDING THE SEQUENTIAL PATH FROM TEAM FUNCTIONING TO CONTINUED VENTURE PURSUIT

Entrepreneurial teams are central to transforming technological opportunities into new ventures, yet how team interaction processes translate into sustained venture pursuit remains insufficiently understood. Drawing on team effectiveness theory (Input–Mediator–Output–Input), we conceptualize venture pursuit as a distal behavioral outcome shaped by two distinct emergent states: perceived commercialization viability, a cognitive assessment of opportunity readiness and validation, and commercialization commitment, a motivational willingness to allocate resources toward commercialization. Using longitudinal data from 106 cohorts of the NSF I-Corps National Program from 2012 to 2021, we test a sequential mediation model linking team functioning to venture pursuit through viability and commitment. Team functioning positively predicts both viability and commitment, and viability strongly predicts commitment. However, team functioning is not directly associated with subsequent venture pursuit. Interestingly, when predicting venture pursuit measured 9 to 16 months later, perceived viability is negatively associated with continuation, whereas commitment is positively associated. These results reveal a competing and sequential mediation structure. High-functioning teams both sharpen evaluative clarity and strengthen motivational engagement. Clearer viability assessments directly reduce continuation, yet indirectly promote it through stronger commitment. The opposing pathways offset one another, yielding a near-zero total indirect effect and explaining the absence of a direct team–venture relationship. By disentangling cognitive evaluation from motivational commitment, this study advances understanding of how team processes shape entrepreneurial trajectories. More broadly, it reveals the dual function of evidence-based entrepreneurial training: such programs can both facilitate venture advancement and enable disciplined disengagement when validation evidence discourages continuation.

 Student Researcher: Qin Liu, Doctoral

 Faculty Advisor: Cesar Bandera

 Data Science & Management



## #807 | CALIBRATING PRODUCTIVE CHALLENGE: A MODULAR VR FRAMEWORK FOR PUBLIC SPEAKING TRAINING UNDER CONTROLLED SOCIAL STRESS

In Human-Computer Interaction (HCI), design philosophies often treat user stress as a purely negative factor to be mitigated. However, the Yerkes-Dodson Law suggests that peak performance requires a “sweet spot” of moderate arousal. This research proposes a novel Virtual Reality (VR) framework designed to challenge the “stress-is-bad” paradigm by precisely calibrating social evaluative threat to optimize training outcomes.

The proposed system utilizes a modular architecture to manipulate four interactive stressors: Audience Size (feeling of crowding and social distance), Audience Dynamics (scaling from supportive to hostile), Temporal Scaffolding (variable countdown constraints), and Active Semantic Interruptions (agent-initiated clarification questions). Through a within-subjects experimental design, we will investigate how these tiered stressors modulate public speaking performance, measured through a multi-modal approach combining expert blinded reviews, automated speech analysis, and perceived anxiety scales.

The primary objective is to identify the functional relationship between system-induced pressure and objective delivery quality. We hypothesize that moderate social friction, such as navigating a distracted audience, will catalyze higher levels of speaker engagement and fluency compared to a zero-stress baseline. The anticipated contribution of this work is two-fold: a technical toolkit for embedding specific social stressors in VR, and a set of design implications for “Productive Friction”. By establishing the interactive thresholds where stress transitions from a performance detriment to a catalyst, this research aims to provide a blueprint for the next generation of adaptive, high-stakes professional training systems.

 Student Researcher: Terry Wei, Doctoral

 Faculty Advisor: Lei Zhang

 Data Science & Management

## #808 | TINKER, TAILOR, TRUST: HOW DEVELOPERS CREATE PRIVACY POLICIES WITH AND WITHOUT AI

Privacy policies govern how apps handle the personal data of millions of users, yet little research has been done about how they are actually created. Most people never read them, but the more pressing question is whether the developers writing them actually know what they are doing.

This study investigated how mobile app developers create privacy policies, with and without AI assistance. We recruited 20 developers from five global regions, Asia, North America, Europe, the Middle East, and Africa, and conducted hour-long semi-structured interviews in which participants described their current workflows and then demonstrated creating a privacy policy live, using a large language model (Claude Sonnet 3.5). We recorded and analyzed both their self-reported practices and their observed behavior during these sessions.

We found that developers rely on a mix of templates, automated generators, and increasingly, LLMs, to produce documents they are legally responsible for but rarely fully understand. Despite using fewer than four prompts on average to generate their policies, most participants rated their trust in the LLM output at eight out of ten or higher and indicated they would submit it to an app store without legal review. Developers consistently treated app store acceptance as a proxy for legal compliance, a standard that, by all available evidence, app stores do not actually enforce.

These findings suggest that as AI adoption grows, the gap between how reliable privacy policies appear and how reliable they actually are will widen, with real consequences for users, regulators, and the developers themselves.

 Student Researcher: Shiva Mayahi, Doctoral

 Faculty Advisor: Nathan Malkin

 Data Science & Management



## #809 | REAWAKENING EVIDENCE: ENHANCING DNA RECOVERY FROM LATERAL FLOW IMMUNOCHROMATOGRAPHIC TESTS TO ADVANCE COLD CASE INVESTIGATIONS

Lateral flow assays (LFAs) are used often in forensics for rapid body fluid identification. A portion of evidence is used for these tests and recovered DNA could be used in further DNA analysis. The work investigates protocol adjustments in order to enhance the recovery of DNA from LFA test strips.

 Student Researcher: Dana Macfarlane, Doctoral

 Faculty Advisor: Sai Casado Zapico

 Data Science & Management

## #810 | THE HIDDEN ROLE OF OXIDATION IN PBSE PHOTOCONDUCTORS

The anticipated future of the infrared market is likely to be characterized by low-cost, uncooled photodetectors operating within the mid-wavelength infrared (MWIR = 3–5  $\mu\text{m}$ ) and long-wavelength infrared (LWIR = 9–12  $\mu\text{m}$ ) spectral regions. These devices will find a multitude of applications, including night-driving assistance, augmented goggles, drone and microsatellite mounts, and machine vision. Lead selenide (PbSe), a technology that has been in existence for 80 years, has recently attracted renewed research interest as a promising option to address the existing MWIR technological gap due to its merits, such as low manufacturing costs and Auger suppression capabilities. Although the two primary, well-established methods for producing PbSe photoconductive films are chemical bath deposition (CBD) and vapor phase deposition (VPD), there is room for improvement by incorporating new solution-processed fabrication techniques to enhance the manufacturability of the detectors. One such solution-processed fabrication can be realized by low-cost quantum dots possessing tunable absorption and emission. In this research, we focus on the hidden role of oxidation in the quantum dot solution-processed fabrication technique for PbSe-based photoconductors without cooling. We introduced oxidation at the quantum dot solid stage, achieving peak responsivity at 3.5  $\mu\text{m}$  and a maximum detectivity  $D^*$  of  $7 \times 10^9$  Jones at room temperature.

 Student Researcher: Ahmad Azuad Yaseer, Doctoral

 Faculty Advisor: Dong Ko

 Data Science & Management



## #811 | CHANGE-POINT DETECTION IN POINT PROCESSES

Many real phenomena undergo significant shifts in their behavior, and change-point detection methods aim to detect these shifts with little delay. One example is Distributed Denial-of-Service (DDoS) attacks. In cybersecurity, these attacks overwhelm servers with internet traffic causing sharp changes in the rate of network traffic. In this scenario, timely detection of the abrupt change in events is crucial for an effective solution.

The conventional approaches for point process change-point detection assume the behavior of the time series is known before and after the event change. However, this assumption proves to be impractical when applied to complex, real world systems. These systems may possess evolving baseline behavior and exhibit unpredictable characteristics after an event change. Fortunately, there is current research that addresses this issue but it only focuses on a single time series. There are many cases when the abrupt change-point is distributed to multiple locations making it difficult for a single point process to fully detect. In these scenarios, we must aggregate information across multiple time series to identify changes.

Our solution to these cases brings us to the focus of our research—change-point detection on multi-stream point processes. We analyze the second derivative of point processes which are proven to perform well in under-specified systems. This allows us to determine threshold conditions that minimize the probability of failure for an aggregate of point processes. In addition to the theory, we use this algorithm to successfully detect abrupt change-points in smooth, non-stationary processes that possess unknown and varying baselines.

 Student Researcher: Fegor Uwuseba, Doctoral

 Faculty Advisor: Anirudh Sridhar

 Data Science & Management

## #812 | VIRTUAL REALITY ONTOLOGY OBJECT MANIPULATION (VROOM) FOR ONTOLOGY-DRIVEN AI AND VR-BASED BIOMEDICAL KNOWLEDGE EXPLORATION

Ontologies are structured knowledge representations that enhance consistency and accuracy in biomedical reasoning by standardizing vocabulary and conceptual relationships. However, traditional ontology authoring tools rely on two-dimensional interfaces, which may limit users' ability to interpret hierarchical and semantic structures. Virtual Reality Ontology Object Manipulation (VROOM) addresses this limitation through an immersive 3D environment for ontology visualization and interaction. Developed in Unity, VROOM supports both single-player and multiplayer VR sessions, allowing multiple users to explore, manipulate, and collaboratively edit the ontology in real time. It enables natural browsing, navigation, and direct manipulation of graphs using tools such as scissors and a glue stick. Participants complete a VR tutorial before engaging in structured task-based assessments covering navigation, inspection, and tasks such as creating, deleting, connecting, and searching for nodes. VROOM is compared with the 2D editor Protégé, with evaluation of recall, navigation efficiency, comprehension, collaboration, and overall user experience. Results indicate that VR-based interaction enhances task performance, supports collaborative engagement, and is generally preferred over 2D interfaces. Future plans to integrate artificial intelligence include Adaptive Guidance, which highlights valid paths or suggests next steps; Gamification, rewarding users for following best practices; and Collaborative Summarization, which generates summary views of edits made by multiple users. These prospective features aim to improve learning, task performance, collaboration, and ontology visualization while maintaining structural integrity and usability in VR.

 Student Researchers: Leandro Paulino, Mayukha Ajeesh Ramsha Nath, Prabhgun Kaur, Abdul Azeez Shaik, Masters

 Faculty Advisor: Margarita Vinnikov

 Data Science & Management



## #813 | THE EVOLUTION OF NEW JERSEY ENTREPRENEURSHIP CURRICULA

How does one decide what is educationally core to a field, and do universities evolve those decisions as the world changes? To explore how academic institutions make and update curricular judgments, we examine entrepreneurship education, a uniquely forward-looking and inherently cross-disciplinary domain. Focusing on entrepreneurship minors across New Jersey universities allows us to observe how programs define “core” entrepreneurial knowledge and whether those definitions shift in response to changing technological and economic conditions. Data were collected by scraping syllabi from New Jersey universities offering entrepreneurship minors and organizing them into a longitudinal database. Using word-cloud visualizations to track keyword prevalence from 2018 to 2025, we examined how course content has evolved over time. This approach allows for comparison of both stability and drift in the conceptual emphases of entrepreneurship curricula across institutions. We find that most programs show remarkably little substantive change across the seven-year period, suggesting a high degree of curricular inertia, while a smaller subset exhibits clear thematic differentiation and niche formation. These results raise questions about how universities make decisions about curricular core, how responsive those processes are to external change, and whether specialization rather than revision has become the dominant mode of academic adaptation.

 Student Researchers: Sergio Giraldo, Shreya Palejwala, Undergraduate

 Faculty Advisor: Mark Annett

 Data Science & Management

## #814 | UTILIZING THE IOS SCALE TO MEASURE CLOSENESS AND INTIMACY IN LONG-DISTANCE AND CLOSE DISTANCE ROMANTIC RELATIONSHIPS

This literature review examines the current landscape of IOS research, statistics and knowledge surrounding long distance dating relationships (LDDRs) among college students and if there is any difference in “closeness” between LDDRs and close distance dating relationships (CDDRs). Current research estimates that around a third of college students actively participate in LDDRs at any given time, with LDDRs being more prevalent in first years. While traditionally, physical separation between two partners was seen as the death of a relationship, with the best way to overcome the nervousness and uncertainty that comes with long distance, recent research suggests that with proper, high quality communication and other techniques are able to maintain relationship stability. Despite thorough analysis of IOS and the different ways to interpret the measure and LDDR dynamics, research specifically focusing on “closeness” differences between LDDRs and CDDRs using IOS is few and far between. By reviewing the present data on IOS and long distance vs close distance relationships, the aim of the review is to provide a deeper understanding of how the idea of “self-other” differs over longer distances. With further research done on IOS differences between the two groups, the hope is that LDDRs may feel validation in their relationship, through higher or equal levels of “closeness” and identity overlap. Additionally, expanding the knowledge on how close LDDRs feel may pave the way for improved relationship management tools/apps that offer meaningful, identity based interactions for couples that are separated by distance.

 Student Researcher: Diego Pinto, Undergraduate

 Faculty Advisor: Abriana Gresham

 Data Science & Management



## #815 | HIGHLANDERS 4 HIGHLANDERS

Highlanders 4 Highlanders (H4H) is a website to connect students through academic tools, backed by research into the overwhelming positive impacts that student-student relationships have on students. It is estimated that around 80% of NJIT students commute and it is proven that being a commuter or resident is a huge factor in a student's social life. However, commuters have a harder time forming academically supportive connections. Within communities of university students, the ability of one group to socialize and connect impacts the rest of the community.

A study conducted in 2022 found that many commuters rely on pre-college friendships to form their social network, making them less inclined to form new connections, including academic ones. They are also more likely to have family or work obligations that prevent them from staying on campus for social events. Studies have shown that commuters often feel disconnected from their university community, contributing towards mental health issues such as depression and generalized anxiety.

We were able to begin developing our solution through researching that academic networks provide emotional support while improving cognitive processing. H4H will help commuters and residents build social and academic connections with each other using a combination of academic and social features which will assist students in developing multiplex relationships. The features in Highlanders 4 Highlanders include artificial intelligence-monitored discussion boards, study tools, and study group finders. We are using frontend, backend, and website hosting tools to apply our research to create a place where students can create their own community.

 Student Researchers: Mia Karpowicz, Emilie Inzinna-Enriquez, Ada Wong, Undergraduate

 Faculty Advisor: Kristen DeGraff

 Data Science & Management

## #901 | A DATA-DRIVEN FRAMEWORK FOR PROACTIVE SAFETY SERVICE PATROL ROUTE OPTIMIZATION

Safety Service Patrols (SSP) are highway assistance programs that provide rapid response to crashes, disabled vehicles, and other incidents, helping to reduce congestion and improve roadway safety. Efficient SSP routing is critical because timely deployment ensures quicker clearance of incidents and minimizes secondary crashes. However, current SSP operations typically rely on static routes, which may not align with dynamic crash risks that vary by time, weather, and roadway conditions. This study presents a scalable, data-driven framework to support proactive Safety Service Patrol (SSP) deployment by linking segment-level crash risk to patrol route design. Using New Jersey's SSP service network as a case study, six major interstates (I-78, I-80, I-280, I-287, I-195, and I-295) were divided into uniform 1-mile segments and historical crashes from 2010 to 2020 were matched to segments based on roadway name, classification, and travel direction. Crash frequencies were then analyzed under 1,152 combinations of scenario-specific conditions defined by time of day, day of week, season, surface, weather, and lighting conditions. Each corridor was modeled as a directed graph, all feasible paths were enumerated exhaustively, and the candidate routes were ranked by cumulative crash frequency. Results reveal that crash risk is highly localized, direction-dependent, and sensitive to operating conditions, with optimal patrol routes varying substantially across scenarios and corridors. Validation using 2023–2024 crash data confirms that the patrol routes identified by the proposed framework remain highly consistent over time, with 74%–95% overall accuracy. The findings underscore the need for adaptive, rather than static, SSP planning. The framework offers actionable guidance for allocating limited patrol resources.

 Student Researcher: Md Tufajjal Hossain, Doctoral

 Faculty Advisor: Joyoung Lee

 Environment & Sustainability



## #902 | PROACTIVE CRASH RISK IDENTIFICATION USING CONNECTED-VEHICLE HARSH BRAKING DATA

Traffic safety analysis traditionally relies on historical crash records, a reactive approach that limits agencies' ability to identify emerging risks before crashes occur. This study evaluates harsh braking (HB) events derived from connected-vehicle telematics as a proactive surrogate indicator of crash risk on New Jersey interstate highways. The analysis integrates over 8.5 million commercial vehicle telemetry records from Drivewyze with approximately 45,000 police-reported crash records collected between July and December 2024.

HB events were identified using a deceleration threshold equivalent to 0.2g and spatially matched to 1-mile interstate roadway segments. Crash records were assigned to the same segments using a GIS-based buffering and attribute validation process. Segment-level crash counts were then modeled using Negative Binomial and Zero-Inflated Negative Binomial regression to account for over-dispersion and excess zeros in the data.

Results indicate a positive and statistically significant association between HB activity and crash frequency. Each additional HB event corresponds to approximately a one percent increase in expected crash count at the segment level. Although the effect of a single event is small, repeated braking activity signals meaningful increases in crash risk.

The findings demonstrate that connected-vehicle telematics can complement traditional crash data by providing early warning of elevated risk, particularly along heavily traveled corridors with frequent merges and congestion. Integrating HB monitoring into safety management programs may support more proactive, data-driven deployment of engineering and operational countermeasures.

 Student Researcher: Md Tufajjal Hossain, Doctoral

 Faculty Advisor: Joyoung Lee

 Environment & Sustainability

## #903 | NEXT-GENERATION TRAFFIC SIGNALS USING GENERATIVE AI AND REINFORCEMENT LEARNING

Traffic congestion in cities is often caused not by roads themselves, but by inefficient traffic signals that cannot respond well to changing conditions such as commuting peaks, sudden demand shifts, or special events. Traditional signal control methods (fixed schedules and sensor-based actuated control) frequently break down during these transitions, creating long delays, wasted fuel, and unnecessary emissions. While Artificial Intelligence (AI) has recently been explored for adaptive traffic signal control, most existing approaches rely on a single AI model that must learn every possible traffic situation. This creates major challenges in scalability, reliability, and real-world interpretability.

This project introduces SmartSwitchLight, a next-generation AI traffic signal control system that combines Reinforcement Learning with Generative AI in a practical and interpretable way. Instead of training one large AI controller, SmartSwitchLight trains multiple smaller "expert" AI controllers, each specialized for a different signal strategy. A Generative AI supervisor (a locally deployed large language model) then monitors real-time traffic conditions and selects the most appropriate expert controller to operate the intersection. Importantly, the supervisor also produces a clear, human-readable explanation for why each decision was made, supporting transparency and human oversight.

SmartSwitchLight was tested using a high-fidelity 24-hour traffic simulation with realistic commuting peaks and event-driven surges. Results show that SmartSwitchLight consistently outperforms fixed-time control, actuated control, and single-AI reinforcement learning systems, achieving up to an order-of-magnitude reduction in total intersection delay, especially during critical demand transitions. These findings demonstrate a promising pathway toward scalable, interpretable, and next-generation AI-powered traffic signal infrastructure.

 Student Researcher: Abolfazl Afshari, Doctoral




 Faculty Advisor: Joyoung Lee

 Environment & Sustainability



## #904 | HEAT STRESS AND PRODUCTIVITY LOSS IN CONSTRUCTION: A PREDICTIVE FRAMEWORK FOR OCCUPATIONAL SAFETY AND ECONOMIC RESILIENCE




Occupational heat stress research is largely confined to single-site analyses, which neglect spatial variability and vertical heat gradients affecting individuals working at different heights. Existing frameworks also remain fragmented, that lack integration of meteorology, physiology, productivity, and economic impacts. This study develops a novel framework with a user interface that integrates a model translating hourly open-access weather data into task-specific productivity loss, schedule delays, and optimized work windows with full economic accounting. First, the framework quantifies heat stress (HS) and comfort levels across eight Asian cities using high-resolution meteorological data. It is then extended to nine California cities exceeding 40°C, where WBGT is estimated from meteorological conditions and ISO-classified metabolic rates. Results show that in several regions, HS and comfort levels are driven more by humidity than by temperature alone. HS declines linearly with building height ( $R^2 = 0.95-0.99$ ;  $-0.023$  to  $-0.029^\circ\text{C}/\text{m}$ ), which indicates systematically greater vulnerability among ground-level workers. For a representative \$10M California project, productivity losses range from 6% (light work) to 29% (heavy excavation), which leads to a 10-day delay and 19.3% project value reduction. Penalty costs exceed combined labor and overhead expenses. Simulated alternative schedules show that early-morning or night shifts reduce heat exposure by 50–100% and recover 28–73% of economic losses, even after accounting for lighting and wage premiums. The study's user-friendly predictive interface enables real-time heat stress estimation, productivity forecasting, and optimized work scheduling. Study reframes occupational heat as a quantifiable and manageable construction parameter, safeguarding both worker health and project economics.

-  Student Researcher: Md. Tushar Ali, Doctoral
-  Faculty Advisor: Mohammad Khalid
-  Environment & Sustainability

## #905 | GRAPH-BASED NEURAL NETWORK PREDICTION OF PEAK FLOOD DEPTH FOR URBAN HAZARD ASSESSMENT

Urban flood hazard assessment is essential for resilience planning and flood damage mitigation and typically requires extensive hydraulic and hydrologic simulations to compile sufficient data for effective decision making. The primary limitation with the traditional approach lies in its computational intensity and the necessity of running full temporal simulations for each storm scenario, limiting feasibility of rapid scenario analysis across multiple events. This study proposes FloodMAGNet, a spatio temporal graph-based neural network that directly predicts maximum flood depth. The framework represents physics-based computational mesh as a graph and integrates rainfall sequences through a single-head attention-based encoder to identify rain pulses relevant to peak response. To better align model optimization with urban hazard assessment objectives, an Importance-Weighted Mean Squared Error (IWMSE) loss is introduced, which prioritizes predictive performance on high-occupancy areas and regulates the influence of extreme depths while preserving overall accuracy across the graph.

The model was evaluated in Englewood, NJ under multiple design storm scenarios. Across the full graph domain, RMSE values remained below 0.27ft, with further reductions below 0.19ft within high-occupancy regions. Hydrologic efficiency metrics indicated strong agreement between predicted and simulated depths across the full graph and further improved within the high-risk subset. To further assess generalization under irregular rainfall conditions, the model was evaluated using an observed storm, with results demonstrating predictive performance consistent with the design-storm scenarios. These findings indicate that the FloodMAGNet framework provides a computationally efficient alternative or supplement to traditional hydraulic simulations for peak flood depth estimation.

-  Student Researcher: Ahmad Ibrahim, Doctoral
-  Faculty Advisor: Michel Boufadel
-  Environment & Sustainability



## #906 | MITIGATING URBAN FLOODING IN RAHWAY: EVALUATING FLOOD MITIGATION APPROACHES USING HYDRODYNAMIC MODELLING

Flooding has been a persistent challenge for New Jersey over recent decades, largely attributed to expanding urban development and an aging stormwater management system. Urban watersheds with significant impervious surfaces generate rapid runoff, overwhelming drainage infrastructure and leading to roadway flooding, property damage, and risks to public safety. The increased frequency of high-intensity rainfall events, along with the resulting impact on municipalities, underscores the need for urgent attention. This research examines the effectiveness of stormwater infrastructure interventions, such as pipes and culverts, alongside distributed storage, in mitigating flooding within the City of Rahway. A two-dimensional hydrodynamic model was developed using HEC-RAS to simulate baseline scenarios of surface runoff, flood routing, and floodplain dynamics for multiple historical rainfall scenarios. Detailed infrastructure data were integrated into the model. The developed model was used to identify hydraulic bottlenecks and recurring flood hotspots. Potential mitigation strategies were evaluated at critical locations, including 1) adding or resizing stormwater pipes to enhance flow capacities and 2) implementing storage areas in strategic locations to reduce peak discharge. Strategies were assessed across varying storm intensities and evaluated based on maximum flood depth and inundation extent. The proposed study identifies infrastructure strategies, or combinations of them, that offer the most significant flood reduction while minimizing negative hydraulic effects both upstream and downstream. This research provides a data-driven framework to support cost-effective and practical flood mitigation planning for urban communities through the integration of physics-based hydrodynamic modeling with practical infrastructure design alternatives.

 Student Researcher: Tamjidul Islam Illin, Doctoral

 Faculty Advisor: Michel Boufadel

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## #907 | COPY OF HYDROPHOBIC ION PAIRING WITH CATIONIC SURFACTANTS ENHANCES THE CAPTURE OF PFAS BY GRANULAR ACTIVATED CARBON

Per- and polyfluoroalkyl substances (PFAS) are persistent contaminants increasingly detected in drinking water sources. Short-chain PFAS are particularly difficult to remove because their high solubility and low intrinsic hydrophobicity limit uptake by conventional processes such as granular activated carbon (GAC). This work evaluates hydrophobic ion pairing (HIP) as a low-cost pretreatment to increase PFAS hydrophobicity by forming electrostatic ion-pairs between anionic PFAS and hydrophobic cationic counterions, thereby increasing apparent hydrophobicity and enhancing their adsorption by GAC.

We quantified HIP-induced changes in PFAS hydrophobicity by measuring octanol–water distribution coefficients (log Dow) for representative PFAS across functional groups (sulfonates, carboxylates, and ether acids) using quaternary ammonium compounds (QACs) spanning multiple alkyl chain lengths under environmentally relevant water quality conditions. HIP increased log Dow for all PFAS, with stronger enhancement for longer-chain QACs and generally larger effects for sulfonates relative to carboxylates. Short-chain PFAS showed the largest relative enhancements (e.g., PFBS up to +1,100%, PFBA up to +427%, GenX +84%).

Based on these distribution results, we then evaluated treatment performance using PFBS adsorption experiments with GAC (4 mg/L) with and without HIP, screening multiple cationic additives at a PFBS: HIP additive molar ratio of 1:2. In 14-day kinetic adsorption tests at equilibrium, PFBS adsorption capacity ( $Q_e$ ) increased from 0.18 mmol/g (no HIP) to 0.30–0.34 mmol/g (~85–94% increase) for QAC-based HIP additives. An amino-acid–derived cationic surfactant, evaluated as a biodegradable alternative, produced 34% increase (0.24 mmol/g). Results thus far suggest that HIP could serve as a cost-effective approach to enhance PFAS removal by GAC filters.

 Student Researcher: Farhaneh Maghsoudi, Doctoral

 Faculty Advisor: Arjun Venkatesan

 Environment & Sustainability



## #908 | PFAS ADSORPTION AND DESORPTION IN SOILS

Per- and polyfluoroalkyl substances (PFAS) are persistent “forever chemicals” that frequently contaminate soils and groundwater. Their environmental mobility is strongly controlled by adsorption to soil minerals and subsequent desorption, yet these processes remain difficult to predict because PFAS exhibit both hydrophobic and hydrophilic behavior and interact with heterogeneous mineral surfaces. This work investigates PFAS adsorption and desorption in soils using an integrated theoretical, computational, and experimental approach.

First, mechanistic adsorption models are developed to better represent PFAS interactions with clay and other soil mineral surfaces, accounting for key contributions such as electrostatic interactions, hydrogen bonding, van der Waals forces, and hydration effects. Next, molecular-level simulations, including molecular dynamics (MD) and density functional theory (DFT), are used to resolve adsorption configurations and energetics, linking microscopic interfacial behavior to macroscopic trends in retention and release. Finally, laboratory adsorption-desorption experiments in porous media are conducted to quantify PFAS retention, desorption kinetics, and the influence of mineral composition and solution chemistry under environmentally relevant conditions.

By connecting molecular-scale mechanisms to measurable transport behavior, this study aims to improve prediction of PFAS fate in subsurface environments and provide practical insight for designing more effective, sustainable remediation strategies at contaminated sites.

 Student Researcher: Ravisha Nuwandi Mudalige, Doctoral

 Faculty Advisor: Jay Meegoda

 Environment & Sustainability

## #909 | URBAN FLOOD MODELING USING HEC-RAS 2D FOR FLOOD RISK ASSESSMENT IN NEW JERSEY'S MUNICIPALITIES

Urban flooding has become an increasing concern in developed municipalities in New Jersey. There are large amounts of impervious surface which reduce infiltration and increase runoff during storm events. Flooding in these municipalities is driven by direct rainfall and limited drainage capacity. A Rain-on-Grid urban flood model was developed using the Hydrologic Engineering Center River Analysis System Two-Dimensional (HEC-RAS 2D) hydraulic modeling software. The scope of this research includes development of a rainfall based hydraulic model using gridded precipitation data, terrain data, watershed boundary, soil map, land use data, and stormwater infrastructure. Multi-Radar Multi-Sensor (MRMS) rainfall data and scaled radar rainfall were used to address spatial and temporal variability of different storm events. Digital Elevation Model (DEM) was used to create terrain, and watershed boundaries were used to define the model domain. Soil and Land Use/Land Cover (LULC) data were incorporated to create an infiltration model. To represent existing drainage systems in the municipalities, culverts and stormwater pipe networks were included in the model. Water level monitoring cameras were installed throughout the municipalities to support model calibration. Simulations were performed to obtain results including water levels, velocity distribution, flow accumulation, flow paths, and flooding extent. The model results were used to locate areas which are susceptible to flooding, evaluate flooding behavior and analyze the causes of flooding in specific areas based on terrain characteristics, drainage limitations, and stormwater pipe capacity. The modeling framework provides a practical and scalable approach for conducting flood risk assessments in multiple municipalities throughout New Jersey. A calibrated flood model can help municipalities identify vulnerable areas, evaluate potential mitigation measures, and improve community resilience to future extreme rainfall events.

 Student Researcher: Md Azmain Rahman, Doctoral

 Faculty Advisor: Michel Boufadel

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## #910 | ENVIRONMENTAL ZINC INDUCES EMBRYONIC-LETHAL CHANGES TO FERTILIZATION ENVELOPE IN THE CTENOPHORE MNEMIOPSIS LEIDYI

Metal pollutants pose significant threats to aquatic animal life. The reproductive impacts of toxic metal exposure are well documented for a wide range of animals, from cnidarians to human beings. One potential method by which metals may inhibit reproduction is by interaction with the fertilization envelope (FE). Fertilization envelopes are made of the extracellular matrix of fertilized eggs that has been lifted away from the cell membrane and hardened by the efflux of calcium and zinc ions respectively. Zooplankton are critical components of marine ecosystems. Ctenophores are abundant and ecologically significant zooplankton. This study investigated the impact of environmental zinc on the model ctenophore, *Mnemiopsis leidyi*. We found that low-level zinc exposure produces a novel, embryonic-lethal phenotype wherein seemingly normal, fully developed embryos are unable to hatch from their fertilization envelopes. This phenotype is brought about by acute zinc exposure at the moment of fertilization. Zinc has been determined to be a priority pollutant by the US Environmental Protection Agency (EPA). Concerningly, the concentration of zinc at which our data indicates a significant negative impact on hatch rate is lower than what the US EPA currently deems safe for aquatic life.

 Student Researcher: Elias Joseph, Doctoral

 Faculty Advisor: Allison Edgar

 Environment & Sustainability

## #911 | EVIDENCE-BASED DESIGN WORKFLOW FOR HOLISTIC NET POSITIVE HEALTHCARE BUILDINGS

Evidence-based design is critical in high-performance building practice because design decisions create linked impacts that require systematic evaluation rather than isolated optimization. Healthcare facilities are among the most energy-intensive commercial building types (U.S. EIA 2018) and typically operate under stringent requirements for patient care, so net positive performance depends on coordinated, data-driven decisions across architecture and engineering.

This project tests an evidence-based design workflow for a healthcare building in Manchester, England, aligned with ASHRAE Standard 189.1 2020 categories for energy, water, IEQ, and materials. A shared BIM supported consistent inputs across simulation platforms. An EnergyPlus BEM (via OpenStudio) was used for parametric comparisons of design interventions, including orientation adjustment, floor plan reconfiguration, and a courtyard.

Envelope and HVAC upgrades reduce heating and cooling loads by 86% and lower total building energy use by 34% relative to the baseline BEM. On-site PV panels generate 139% of energy use, enabling net positive operational energy. Water strategies use native landscaping, high-efficiency fixtures, and rainwater and greywater recycling. IEQ outcomes improve through daylighting and planning measures, with the courtyard increasing daylight distribution by 32% and improving view access while supporting ventilation goals. Materials impacts were reduced through an LCA-informed strategy that replaced higher-impact assemblies with lower-carbon options, including a mass timber structure and bio-based insulated enclosure systems, achieving a 78% reduction in embodied carbon. The project won first place in the 2025 Setty Family Foundation Net Zero Energy Design Competition, an international competition.

 Student Researchers: Minkyong Park, Jeongseo Lee, Mingzhe Li, Austin Chen, Jacob Swanson, Doctoral

 Faculty Advisor: Hyojin Kim

 Environment & Sustainability



## #912 | ASSESSING DROUGHT STRESS WITHIN COLORADO'S FORESTS

Climate change has threatened forest ecosystems via drought-induced stress. Predicting forest die-off requires understanding the drivers behind an ecosystem's vulnerability to drought. However, complex responses to drought-induced stress within heterogeneous forests cast uncertainty on conventional methods for determining an ecosystem's response to drought. This study focuses on identifying the factors responsible for drought stress within the state of Colorado by synthesizing a biogeography of drought response in the region. We evaluated remotely sensed vegetation indices for drought-affected forests in Colorado over a 19-year period from 2000 to 2019. Anomalous decreases in canopy greenness were then compared to spatial distributions of biogeographic properties such as vegetation type, soil and water table depth. We expect to find that drought-induced stress will increase in deep-water-table forests exposed to drought; that drought stress will associate with spatial variations in elevation; and that areas exposed to multiple drought events will experience greater long-term stress. Our findings will enable better prediction of drought stress and potentially inform preventative measures to mitigate the ecological impact of drought.

 Student Researcher: Isaiah Rejouis, Doctoral

 Faculty Advisor: Xiaonan Tai

 Environment & Sustainability

## #913 | REAL-TIME MULTI-SPECTROSCOPIC MONITORING OF MEMBRANE SURFACE USING A MICROFLUIDIC MEMBRANE-MIMIC PLATFORM

Membrane fouling remains a critical challenge in water treatment, biotechnology, and pharmaceutical processing, limiting membrane efficiency and operational lifetime. In this work, we developed an integrated microfluidic membrane platform that combines electrochemical impedance spectroscopy (EIS) with on-chip surface-enhanced Raman spectroscopy (SERS) to enable real-time analysis of fouling kinetics and interfacial molecular processes under controlled flow conditions. A 0.45  $\mu\text{m}$  porous membrane was embedded in a cross-flow microfluidic device and used simultaneously as both a filtration interface and a sensing substrate. Model polystyrene particles were used to systematically investigate concentration-dependent fouling behavior. Continuous EIS measurements revealed a concentration-driven increase in charge-transfer resistance, and kinetic modeling using a pseudo-first-order framework showed that fouling progression was primarily governed by surface accumulation rather than pore blockage. To gain molecular-level insight into surface processes, silver nanoparticle (AgNP)-functionalized membranes were integrated to create plasmonic "hot spots" for SERS analysis. Under dynamic flow, 4-aminothiophenol (4-ATP) was introduced into the device, and distinct in situ SERS spectra were captured, confirming the platform's ability to probe chemical interactions occurring at the membrane interface. This multimodal EIS-SERS microfluidic platform establishes a powerful approach for correlating electrochemical signatures with molecular-level surface analysis, providing a foundation for predictive fouling studies and future biosensing applications such as antibody-antigen interactions.

 Student Researcher: Najamuddin Naveed Khaja, Doctoral

 Faculty Advisor: Sagnik Basuray

 Environment & Sustainability



## #914 | RAPID NON-TARGETED DETECTION OF PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS) IN ARTIFICIAL TURF

Artificial turf (AT) fields are widely used across the United States, with over 130,000 fields and 1,200–1,500 new fields installed annually. This has raised toxicological concerns regarding potential exposure to per- and polyfluoroalkyl substances (PFAS), a diverse group of >14,000 anthropogenic compounds known for environmental persistence and bioaccumulative potential. PFAS are used in polymer coatings and plastic manufacturing associated with AT production. However, little is known about which PFAS are present or their environmental transformation during AT lifetime. The objective of this study is to identify PFAS in AT fields to contribute to evidence-based environmental decision-making. Sample collection of AT fibers included weathered and non-weathered field samples. Following collection, we performed a non-target analysis using paper spray mass spectrometry (PS-MS), an innovative rapid ionization technique that enables direct analysis from minimal extraction to detect PFAS in each AT field component. After PFAS detection (i.e., presence/absence), tandem mass spectrometry was used to confirm the identity and structure of PFAS species. Over twenty PFAS species were identified, including perfluoropentanoic acid, in weathered and non-weathered samples, suggesting that PFAS is produced during manufacturing in addition to environmental transformation over AT's lifetime. This study demonstrates that PS-MS provides rapid, highly sensitive, and accurate analysis of PFAS in AT fields. Overall, multiple PFAS were detected in synthetic grass fibers of AT fields, which may contribute to human exposure and environmental contamination.

 Student Researchers: Stephanie Martinez, Christopher De Oliveira-Cordova, Doctoral

 Faculty Advisor: Genoa Warner

 Environment & Sustainability

## #915 | OVARIAN TOXICITY OF BENZYL PARABEN AND BUTYL PARABEN

Benzyl paraben (BzP) and butyl paraben (BuP) are chemicals that are used as preservatives and antimicrobial agents in cosmetics, pharmaceuticals, and foods. BzP and BuP have been detected in urine, placental tissue, and ovarian follicular fluid and are understudied with regards to their endocrine activity. In this research we tested the hypothesis that BzP and BuP are toxic to the ovary and behave similarly to other structurally similar endocrine disrupting chemicals. To investigate these concerns, we studied the impact of exposure to BzP and BuP on the mouse ovary.

We performed 96 hr in vitro studies in which follicles were dissected from ovaries of adult female CD-1 mice and cultured with vehicle control (DMSO) or 0.1–100 µg/mL of BzP or BuP. At the end of the culture period, media were collected to analyze steroid hormone concentrations and follicles were collected to analyze gene expression. We used enzyme linked immunosorbent assays (ELISA) to measure hormones. We also used quantitative polymerase chain reaction (qPCR) to assess gene expression related to steroidogenesis, cell cycle, and apoptosis.

We found that 100 µg/mL BzP and BuP were highly cytotoxic to follicles. BzP at 1 µg/mL significantly increased levels of estradiol and BzP at 10 µg/mL also significantly increased levels of testosterone. Fabp4 and Cdkn1a were significantly upregulated from 10 and 1 µg/mL BzP.

Our results suggest that BzP and BuP are cytotoxic to the ovary and disrupt hormone levels and signaling at doses below cytotoxicity, suggesting potential endocrine disruption.

 Student Researcher: Courtney Potts, Doctoral

 Faculty Advisor: Somenath Mitra

 Environment & Sustainability



## #916 | MECHANICAL BREAKDOWN OF MICROFIBERS IN SAND AND THE GENERATION OF MICROPLASTICS

The ongoing fragmentation of plastic waste into highly mobile and reactive microplastics has turned microplastic pollution into a critical threat to the resilience of natural systems. As plastics fragment in the environment, photo-oxidation driven by UV exposure progressively alters their chemical structure, inducing bond scission, surface oxidation, and microcrack formation that can weaken the material. Despite growing concern, the subsequent mechanical breakdown of these aged particles within sedimentary systems remains insufficiently understood. Therefore, this study examines how synthetic microfibers degrade in sand under low-energy shear conditions, aiming to mimic beach and dune environmental behavior. By assessing surface damage and sub-micron fragment release across different sand loadings and degrees of photo-oxidation, the research clarifies how oxidative weakening, stress, abrasion, and fragmentation interact. This work emphasizes that environmental aging and mechanical abrasion jointly govern the production of small fragments, the most persistent forms of plastic pollution, highlighting the need for integrated pollution management approaches that address this hidden source of microplastics within natural substrates.

 Student Researcher: Maria Nour Assi, Doctoral

 Faculty Advisor: Michel Boufadel

 Environment & Sustainability

## #917 | ASSESSING REMBIND AMENDMENTS FOR PFAS IMMOBILIZATION FROM MUNICIPAL SLUDGE BYPRODUCTS

Per- and polyfluoroalkyl substances (PFAS) are persistent contaminants frequently observed in municipal wastewater sludge and the biosolids generated from it. When these biosolids are applied over land, they can act as a source of PFAS to agricultural soils, crops, groundwater and nearby surface waters, creating environmental and regulatory issues. This study evaluates the performance of two PFAS-binding adsorbents, RemBind100 and RemBind100X, for reducing PFAS release from sludge-derived pellets. Bench scale experiments were conducted using raw sludge, sludge-cake, mixer solids, and dried pellets collected from a municipal sludge-processing facility. With varying sorbent dosages, PFAS leachability and extractability (EPA 1633 method) were assessed relative to unamended controls. RemBind100X demonstrated superior performance compared to RemBind100, achieving reduced  $\Sigma 10$ PFAS leachability of  $78.81 \pm 1.32\%$  and  $91.48 \pm 2.64\%$  at 0.3% and 0.6% (w/w) additions, respectively. PFAS extractability results further indicated stronger PFAS retention in amendments.  $\Sigma 10$ PFAS recoveries decreased to  $76.91 \pm 3.06\%$ ,  $60.37 \pm 5.97\%$ , and  $59.37 \pm 2.82\%$  in raw sludge amended with 0.3%, 0.6%, and 1.2% of RemBind100 while further lower recoveries were observed for RemBind100X, with only  $52.59 \pm 0.09\%$  and  $49.72 \pm 1.33\%$  recovered at 0.3% and 0.6%, indicating stronger retention, greater stability, and more effective immobilization. Overall, the results suggest that amendment at the raw sludge stage, where moisture content is highest, is the most effective point of application, and both sorbents showed clear dose-dependent improvements in PFAS immobilization. These findings demonstrate that sorbent-based amendments represent a practical and scalable strategy to limit PFAS mobility and reduce the potential for environmental transport from land-applied biosolids.

 Student Researcher: Santhoshi Chitthaluri, Doctoral

 Faculty Advisor: Arjun Venkatesan

 Environment & Sustainability



## #918 | IMPACT OF CLIMATE CHANGE ON THE SALINIZATION OF COASTAL WETLANDS

Climate change intensifies salinization in wetlands through multiple mechanisms. Rising sea levels results in increased saltwater intrusion which alters the hydrology of wetland ecosystems, increasing the salinity of soils and surface water. Additionally, increased evaporation rates, driven by rising temperatures and changing precipitation patterns, are likely to concentrate salt on the wetland soil surface (ultimately resulting in salt crusts). These processes can have profound effects on wetland vegetation, shifts in species composition, reduced biodiversity, and loss of habitat for both terrestrial and aquatic organisms. They can also impact wetland functions such as water filtration, flood mitigation, and carbon sequestration. Mitigating the effects of climate change on wetland salinization requires comprehensive management strategies that address both the drivers of salinization and the resilience of wetland ecosystems to changing environmental conditions.

In this context, for the past two years, I worked alongside the NJIT-CNR team and installed groundwater salinity monitoring systems in two regions: 1) Jacques Cousteau National Estuarine Research Reserve in Tuckerton, NJ near the Rutgers Marine Field Station and 2) Riverbend Wetlands Reserve in Secaucus, NJ, near the Meadowlands Environmental Research Institute. In both regions, the team installed three Conductivity Temperature, and Depth (CTD) sensors at three different depths (0.2, 0.4, and 0.6 m) to further monitor porewater salinity and understand the broader phenomenon of coastal aquifer salinization.

 Student Researchers: Abdul Razzak Doughan, Joseph Miller, Doctoral

 Faculty Advisor: Michel Boufadel

 Environment & Sustainability

## #919 | RAPID DESTRUCTION OF PFAS BY CHEMICAL DEFLUORINATION

Per and polyfluoroalkyl substances (PFAS) termed “forever chemicals” are anthropogenic pollutants which are persistent, bioaccumulative and toxic to the environment. Their diverse applications in industrial and household products emanate from their hydrophobic and oleophobic properties. However, the negative impacts of PFAS contamination on human health and the ecosystem are issues of major concern. Although current innovative technologies and synergistic approaches exist, they are limited by longer reaction time, inert conditioning, high energy input and uncontrolled reaction with water. The strong multiple carbon-fluorine (C-F) bonds are indicative of their strong resistance to most chemical, thermal and biological degradation mechanisms. Our current study elucidates and presents a promising strategy to degrade PFAS in sub-minute and at room temperature.

Here we show a chemical reaction mediated by the presence of sodium metal complexed in a polar aprotic solvent, that defluorinate all types of PFAS whilst converting them into innocuous fluoride ions and exhibit hydrolytically controlled degradation. Monomeric PFAS like Perfluoroalkyl carboxylic acids decarboxylate (rate limiting step) into perfluoroalkyl intermediate ions and later degrade into sodium fluoride ions (yielding 62 to ~100%) within 5 minutes. This allows for fluoride ion recovery and recycling in PFAS as inorganic salts. Perfluoroalkyl sulfonates degrade completely with >90% defluorination with minimal fluorocarbon intermediates formed. This offers a promising approach to mineralization of other oligomeric and polymeric PFAS.

 Student Researcher: Ebenezer Etsiwah, Doctoral

 Faculty Advisor: Arjun Venkatesan

 Environment & Sustainability



## #920 | COPPER-BASED LAYERED METAL CATALYSTS WITH RICH OXYGEN VACANCIES FOR EFFICIENT DEGRADATION OF PHENOLIC POLLUTANTS VIA PEROXYMONOSULFATE ACTIVATION UNDER HIGH SALINITY CONDITIONS

High-salinity organic wastewater is usually generated in chemical manufacturing processes. Due to the presence of high strength refractory organic pollutants and inorganic salt ions, improper disposal can cause serious harm to the ecosystem. However, the degradation of organic pollutants through most advanced oxidation processes is significantly hindered by side reactions with coexisting inorganic ions. This study aims to enhance the degradation of organic pollutants in high-salinity systems by modifying the reaction pathways of reactive oxygen species (ROS) through the construction of oxygen vacancies on the novel layered metal catalyst surface to enable a non-radical pathway for pollutant degradation, where singlet oxygen ( $^1O_2$ ) acted as the main reactive species and was less affected by inorganic ions. This catalyst achieved over 80% degradation of phenol in a solution containing 200 mM of inorganic salt ions through peroxymonosulfate activation. The catalyst exhibited excellent catalytic performance across a wide pH range (3–11), as indicated by the stable and high degradation efficiencies of over 90% for different pollutants such as phenol, bisphenol A, and 2,4-dichlorophenol within 30 min. Furthermore, after five cycles (300 min) of degradation, the catalyst still maintained a degradation efficiency of over 80%. The results confirmed that the construction of oxygen vacancies enabled the catalyst to achieve effective degradation of refractory organic pollutants even in high-salinity environments. This study not only provides an effective catalyst design strategy for treating high-salinity organic wastewater but also offers new insights into the role of oxygen vacancies in catalytic degradation mechanisms.

 Student Researcher: Haodong Jia, Doctoral

 Faculty Advisor: Wen Zhang

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## #921 | COST EFFECTIVE REMOVAL OF PFAS FROM DRINKING WATER USING ENHANCED COAGULATION

Per- and polyfluoroalkyl substances (PFAS) are highly persistent and toxic pollutants that pose significant challenges to water and wastewater treatment systems. Conventional coagulation-flocculation processes, although widely used for drinking water treatment, show limited effectiveness in removing PFAS, especially short-chain variants. This study presents a practical hydrophobic ion-pairing pretreatment strategy designed to integrate seamlessly with existing coagulation-flocculation systems to enhance PFAS removal performance. The approach utilizes hydrophobic chemical additives with cationic functional groups that neutralize the charged heads of PFAS molecules, forming hydrophobic ion-pair complexes. These complexes exhibit stronger hydrophobic interactions with flocs, thus enhancing their removal. Cetrimonium chloride (CTAC), a 16-carbon quaternary ammonium compound, was used as the hydrophobic additive, and its performance was compared across three commonly used coagulants: alum, ferric chloride, and polyaluminum chloride. Batch experiments conducted using a jar test apparatus demonstrated that while all coagulants performed similarly for long-chain PFAS removal, polyaluminum chloride achieved superior removal of short-chain compounds. A low CTAC dose (1 mg/L) was able to achieve >80% removal of long-chain PFAS, whereas higher doses (2.5-5 mg/L) were required to improve the removal of short-chain PFBA, PFBS, and GenX, yielding removal efficiencies of 15-45%. The PFAS removal performance was influenced by both chain length and functional groups, with sulfonates showing superior removal compared to carboxylates, and long chains outperforming short chains. Overall, this work highlights a cost-effective pretreatment strategy that substantially improves the efficacy of conventional drinking water treatment methods for mitigating PFAS in drinking water.

 Student Researchers: Bishnu Pandey, Afaq Ahmad, Doctoral

 Faculty Advisor: Arjun Venkatesan

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## #922 | AMMONIA RECOVERY FROM WASTEWATER USING INTEGRATED UNABLE ELECTROCHEMICAL SYSTEMS

This project develops a fully electrified membrane platform for direct nitrate ( $\text{NO}_3^-$ ) upcycling from wastewater into ammonia ( $\text{NH}_3$ ) and value-added ammonium sulfate ( $(\text{NH}_4)_2\text{SO}_4$ ), providing a sustainable alternative to conventional nitrogen removal and Haber–Bosch ammonia synthesis. Instead of energy-intensive nitrification–denitrification ( $\sim 11.7\text{--}12.5 \text{ kWh}\cdot\text{kg}\cdot\text{N}^{-1}$ ) or fossil-fuel-driven  $\text{N}_2$  fixation, the system integrates electrochemical  $\text{NO}_3^-$  reduction with paired electrolysis to enable proton and hydrogen transfer across cathodic and anodic chambers without external acid/base addition.

The electrified membrane consists of a  $\text{CuO@Cu}$  foam cathode coupled with a hydrophobic PTFE membrane, enabling simultaneous  $\text{NO}_3^-$  reduction and  $\text{NH}_3$  recovery. At a partial current density of  $63.8 \pm 4.4 \text{ mA}\cdot\text{cm}^{-2}$ , the system achieved 99.9%  $\text{NO}_3^-$  removal from 150 mM feed within 5 h and 99.5%  $\text{NH}_3$  recovery, corresponding to a production rate of  $3100 \pm 91 \text{ g}\cdot(\text{NH}_4)_2\text{SO}_4\cdot\text{m}^{-2}\cdot\text{d}^{-1}$  and an energy consumption of  $21.8 \pm 3.8 \text{ kWh}\cdot\text{kg}^{-1}\cdot(\text{NH}_4)_2\text{SO}_4$ . Density functional theory (DFT) calculations reveal that in situ  $\text{Cu}^{2+}\rightarrow\text{Cu}^+$  transformation generates highly dynamic active species that promote selective  $\text{NO}_3^-$  reduction to  $\text{NH}_3$ . A pilot-scale reactor ( $0.16 \text{ m}^2$  anode area) validated scalability using real wastewaters, including RO retentate, ion exchange brine, and landfill leachate. For 10 mM  $\text{NO}_3^-$  feed,  $\sim 7.87 \text{ mM}$   $\text{NH}_3$  was recovered within 100 min, while high-strength wastewater ( $\sim 211 \text{ mM}$   $\text{NO}_3^-$ ) achieved  $\sim 47 \text{ mM}$  removal in 120 min. Overall, this work demonstrates a scalable, chemical-free, and energy-competitive pathway for circular nitrogen management and decentralized fertilizer production.

 Student Researcher: Jiahe Zhang, Doctoral

 Faculty Advisor: Wen Zhang

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## #923 | NANOBUDDLE-ENRICHED HYDROGELS FOR SUSTAINABLE AGRICULTURE: ENHANCING WATER AND NUTRIENT DELIVERY TO BOOST PLANT GROWTH

Agricultural irrigation accounts for nearly 80% of global freshwater withdrawals and increasing drought frequency threatens crop productivity and long-term food security. Excessive fertilizer use further contributes to soil degradation and nutrient runoff, highlighting the need for resource-efficient agricultural technologies. This study develops a precision agriculture strategy integrating commercial hydrogels with air and nitrogen nanobubble (NB) water to enhance soil moisture retention, oxygen delivery, and nutrient utilization. Nanobubble-infused hydrogels exhibited high swelling capacity ( $297.97 \text{ g}\cdot\text{g}^{-1}$ ) and rapidly adsorbed  $\sim 2.0 \times 10^8 \text{ NBs}\cdot\text{mL}^{-1}$  within 30 min. Water retention remained above 50% after four days and was fully released by Day 10, demonstrating sustained moisture availability. Release-profile analysis confirmed controlled discharge of water, nutrients, and nanobubbles. Air-NB hydrogels increased dissolved oxygen release by 38% relative to distilled-water controls, while nitrogen-NB hydrogels showed prolonged nanobubble stability and slower gas diffusion. Kale (*Brassica oleracea* var. *acephala*) grown under six irrigation treatments revealed that NB–hydrogel combinations significantly improved leaf number, plant height, stem diameter, chlorophyll content, and fresh biomass compared to individual NB or hydrogel treatments. These results demonstrate a synergistic hydrogel–nanobubble interaction that enhances root-zone aeration and resource-use efficiency, offering a scalable platform for climate-resilient and sustainable agriculture.

 Student Researcher: Yining Zhang, Doctoral

 Faculty Advisor: Wen Zhang

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## #924 | OMNIPHOBIC FAS/PANI/FE3O4 INTERFACE ENABLING ROBUST INDUCTION-HEATING MEMBRANE DISTILLATION FOR DIVERSE SALINE WATER TREATMENT

Thermal desalination technologies face growing demands for improved energy efficiency and long-term operational stability under high-salinity and complex wastewater conditions. Conventional membrane distillation (MD) relies on bulk heating of the entire feed stream, resulting in substantial heat losses and vulnerability to membrane wetting, fouling, and scaling. This study develops an induction-heated membrane distillation (IH-MD) platform integrating localized interfacial heating with omniphobic membrane engineering. A  $\text{Fe}_3\text{O}_4/\text{PANI}$  coating enables rapid induction-driven surface heating, achieving membrane temperatures above  $90^\circ\text{C}$  within seconds, while a fluorinated silane layer forms a low-surface-energy omniphobic interface without compromising thermal responsiveness. COMSOL simulations confirm confined heat localization at the membrane interface, minimizing thermal dissipation. Experimental MD tests demonstrate stable vapor flux ( $1.8\text{--}2.0\text{ kg m}^{-2}\text{ h}^{-1}$ ) and  $>99\%$  salt rejection under saline feeds. In contrast to non-FAS coated membranes that exhibit surfactant-induced wetting and rapid flux collapse during organic fouling, the FAS-modified membranes maintain stable performance under SDS and humic acid conditions. These findings reveal a synergistic integration of induction heating and surface engineering that enhances thermal efficiency and operational durability, providing a scalable strategy for next-generation energy-efficient desalination systems.

 Student Researcher: Guangyu Zhu, Doctoral

 Faculty Advisor: Wen Zhang

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## #925 | ELECTRIC-FIELD-DRIVEN INTERFACIAL DYNAMICS, COALESCENCE BEHAVIOR AND DEPOSITION OF OIL DROPLETS

Large volumes of produced water are generated during petroleum extraction, and separating tiny oil droplets from water remains a major treatment challenge. These droplets are often stabilized by natural surfactants and dissolved salts, making them resistant to conventional separation methods. Electric fields offer a controllable and lower-chemical alternative for enhancing oil–water separation, but the detailed mechanisms behind droplet motion and merging are not fully understood.

This research examines how externally applied electric fields influence oil droplet movement, deformation, coalescence, and surface deposition. Using high-speed optical microscopy, laser-based droplet sizing, electrochemical quartz crystal microbalance (eQCM), and UV-Vis's spectroscopy, the study tracks droplet behavior across multiple scales. Weak electric fields cause droplets to migrate without merging. As field strength increases, droplets elongate, align, and coalesce more rapidly. Surface measurements reveal voltage-dependent mass accumulation, showing that stronger fields accelerate droplet attachment and restructuring.

Oil chemistry plays an important role, as viscosity and polarity affect droplet stability and coalescence thresholds. Together, these results provide a mechanistic understanding of how electric fields can improve oil-water separation. The findings support the design of more energy-efficient electrocoalescers and contribute broader insight into electrically driven processes in multiphase fluid systems relevant to environmental engineering and water treatment.

 Student Researcher: Sowmya Atukuri, Doctoral

 Faculty Advisor: Wen Zhang

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## #926 | PHTHALATE REPLACEMENTS SHOW SIMILAR EFFECTS AS PHTHALATES ON GENE EXPRESSION AND HORMONE PRODUCTION IN MOUSE OVARIAN FOLLICLES

Phthalates are phthalic acid esters used as plasticizers to make plastics more flexible and durable. The most common phthalates are di(2-ethylhexyl phthalate (DEHP) and benzylbutyl phthalate (BzBP), which metabolize in the body to mono(2-ethylhexyl) phthalate (MEHP) and monobenzyl phthalate (MBzP). Previous studies indicate that these phthalates are endocrine disrupting chemicals, leading to the development of replacements. Terephthalates are structural isomers used as alternatives in plastic products for both commercial and industrial use. However, there is a lack of research on if alternatives show similar toxicity in the reproductive system. To study this, ovarian follicles were collected from adult female CD-1 mice and cultured for 96 hours in vehicle control, 100 µg/mL of MEHP, mono(2-ethylhexyl) terephthalate (MEHTP), MBzP, or monobenzyl terephthalate (MBzTP). Afterwards, follicles were collected to analyze gene expression of steroidogenesis, apoptosis, and cell growth and proliferation genes using quantitative polymerase chain reaction (qPCR). Media were collected to measure hormone levels using enzyme-linked immunosorbent assays (ELISAs). Phthalates significantly impacted the majority of genes studied, with similar effects seen between phthalate and terephthalates. MEHP and MEHTP impacted steroidogenic genes. Peroxisome proliferator-activated receptor (PPAR) controlled genes were significantly impacted. MEHP and MEHTP treatments decreased estradiol levels, and all treatment groups significantly increased progesterone levels. Our findings suggest that though ring substitution may change the magnitude of phthalate effects, terephthalates show similar impacts on gene expression and hormone production. This similarity means that terephthalates may also lead to endocrine disruption and health concerns, specifically for female reproductive health.

 Student Researcher: Raulle Reynolds, Masters

 Faculty Advisor: Genoa Warner

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## #927 | LIFE ON THE RIVER—LEVERAGING INTERDISCIPLINARY SERVICE-LEARNING EXPERIENCES TO TACKLE COMPLEX SUSTAINABILITY PROBLEMS

In an era of increasingly complex sustainability challenges that actively impact communities in real-time, a more collaborative, interdisciplinary, and active approach is required to effectively address these issues. Over the course of several months under faculty advisors, a student research team of diverse disciplines and academic backgrounds worked to investigate the various impacts and harms of the Passaic River on surrounding communities. This poster presentation aims to discuss the work of two of those students, each from one of the research initiative's two interconnected focuses: contaminant testing and eco-cultural mapping, and riverfront planning and redevelopment.

Both students were placed within a multi-faceted environmental engineering problem that required boots on the ground on the local case study site, the Second River. Their active engagement with the site and the issues at hand ranged from water sampling for contaminant testing, to site visits to ascertain urban contexts and site conditions. They also drew from varying disciplinary perspectives amongst their peers within the research team as well as external expert collaborators, adopting new ways of thinking, filling gaps in technical and conceptual knowledge, and considering additional factors in their inquiries. The act of doing forced them to confront and adapt to issues that arose in the real-world setting, as well as to engage with stakeholders, the 'real people' at the center of the project. This iterative research / design process yielded an actionable framework of findings and further questions alike for the identification, development, and potential implementation of humanistic and environmental solutions on the Second and the Passaic River at large.

 Student Researchers: Tristan Cunanan, Pooja Datir, Undergraduate

 Faculty Advisor: Ashish Borgaonkar

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## #928 | VERDURA AUTOMATIONS

Verdura Automations is developing a plug and play greenhouse automation system designed specifically for small commercial greenhouse operators and serious hobbyist growers who lack access to affordable, reliable automation solutions. These growers manage highly sensitive biological environments with limited labor and capital, where a missed irrigation cycle, poor ventilation, or unstable climate conditions can quickly result in crop loss, reduced yields, and financial strain. Despite the critical need for automation, existing enterprise level systems are often too expensive, complex, and difficult to integrate, while lower cost consumer products are fragmented, inconsistent, and not built for commercial reliability.

Verdura bridges this gap by offering a modular automation platform that connects directly to existing greenhouse infrastructure. Rather than requiring growers to replace their current equipment, Verdura integrates with irrigation lines, ventilation systems, and climate control components to automate operations efficiently and intelligently. Through a combination of adaptable hardware and user friendly software, growers can monitor and manage their greenhouse conditions with greater precision and less manual oversight.

By reducing labor demands, improving environmental consistency, and minimizing the risk of crop loss, Verdura enables growers to operate more efficiently and sustainably. The system is built to scale with the grower, providing accessible automation that supports productivity and long term growth without the high costs and complexity of traditional solutions.

 **Student Researchers:** Santiago Garcia, Kermina David, Undergraduate

 **Faculty Advisor:** Oksana Manzhura

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## #929 | MAPPING THE INVISIBLE: SPATIALLY-TARGETED INDOOR ENVIRONMENTAL QUALITY MONITORING

Indoor environmental quality (IEQ) encompasses the physical characteristics of indoor environments that can affect occupants' health, well-being, and performance, including thermal comfort, indoor air quality (IAQ), lighting, and acoustics. However, conventional IEQ monitoring approaches are often expensive, which limits their spatial coverage and ability to capture the temporal variability of conditions experienced by occupants. Therefore, this project aims to develop and evaluate spatially-targeted IEQ monitoring configurations tailored to diverse indoor environments and pair this effort with an IEQ awareness campaign to enhance future architects' understanding of IEQ dynamics.

This project builds on the earlier development of an affordable and portable IEQ toolkit called Q-IE (Quality of Indoor Environment). The original Q-IE consists of two prototypes with different levels of detail: DM (Detailed Monitoring) and BM (Basic Monitoring), measuring IEQ parameters and occupancy using open-source platforms. This current project introduces three Q-IE BM+ prototypes (i.e., BM+Air, BM+Light, and BM+Comfort), each based on the original BM configuration with one or two additional sensors selected to capture space-specific environmental priorities. Rather than replicating the comprehensive DM sensor array, these BM+ variants implement refined, spatially targeted monitoring configurations.

Twenty Q-IE BM+ units will be deployed at NJIT Weston Hall to map IEQ data across studios, lecture halls, and office spaces. In parallel, the project will launch an interactive IEQ awareness campaign to engage daily occupants, translate technical data into accessible insights, and demonstrate that performance-based design must extend beyond energy efficiency metrics to prioritize occupant well-being.

 **Student Researchers:** Austin Chen, Alla Morozova, Sudiksha Sahu, Owen Kennedy, Undergraduate

 **Faculty Advisor:** Hyojin Kim

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## #930 | COMPARING HALICTUS LIGATUS MORPHOLOGY IN NEW JERSEY BROWNFIELDS AND GREENFIELDS

With the increasing amounts of pollutants in our ecosystems and the decline of native bee populations, it is essential to understand how native bee populations respond to environmental contamination. This study investigates the differences in morphology of our native bee species, *Halictus ligatus*, comparing those found in brownfields and greenfields in New Jersey collected between 2012-2013. Brownfields are abandoned commercial or industrial sites suspected of contamination, while greenfields are old agricultural sites that are not expected to be contaminated. To assess how *Halictus ligatus* responds to these different habitats, we measured the intertegular distance (an indicator of body size) and head size in female specimens using linear morphometric techniques. We found that the heads of these bees were smaller in brownfields than those in greenfields. This could be a result of contamination or differences in floral resource availability. Building on our findings, we are currently using linear morphometric techniques to measure wing asymmetry. We hypothesize that wing asymmetry, which may be a marker of pollution-related developmental issues, will be higher in bees from brownfield sites compared to those from greenfield sites.

 Student Researchers: Linda Morin, Brock Shahinian, Vita Infurna, Jonathan St Jean, Undergraduate

 Faculty Advisor: Caroline Devan

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## #931 | IMPACT OF COMBINED EXPOSURE TO NANOPLASTICS AND PHTHALATES ON PLACENTAL AND FETAL DEVELOPMENT

Plastics degrade into nanoplastics (NPs) through weathering, whereas phthalates are chemicals added during plastic production to improve plastic durability and flexibility. Phthalates and NPs may disrupt female reproductive processes. Both can enter the body via inhalation, dermal contact, or ingestion and can translocate to organs, including the placenta, which is essential for embryonic development. Humans are continuously exposed to both substances, yet research on the impacts of co-exposure on placental health remains limited. To test our hypothesis, that co-exposure to phthalates and polyethylene terephthalate (PET) nanoplastics would have a greater impact on placental and fetal development compared to exposure to either substance alone, pregnant CD-1 mice were dosed with vehicle control, 200 nm secondary lab-generated PET nanoplastics at 2 mg/kg/day, a phthalate mixture at 200 µg/kg/day, or a combination of NPs and phthalates for 10 gestational days. Following the dosing, the placentas and fetuses were collected to identify exposure-related changes. Several maternal and fetal characteristics were also analyzed to identify trends related to exposure. Our results showed no statistically significant differences between the treatment groups among placental and fetal weights, and all observed maternal and fetal characteristics. Future studies should analyze the effects of co-exposure to NPs and phthalates at the molecular level, focusing on gene expression in the transforming growth factor beta (TGF-β) pathway, which is critical for placental structure development, immune response, and trophoblast invasion, using quantitative polymerase chain reaction (qPCR). This study highlights potential health impacts of co-exposure to both phthalates and nanoplastics.

 Student Researcher: Mariam Ali, Undergraduate

 Faculty Advisor: Genoa Warner

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## #932 | ENDOCRINE-DISRUPTING EFFECTS OF A COMMON PRESERVATIVE

More than 90% of the population carries detectable levels of endocrine-disrupting chemicals (EDCs), compounds that interfere with hormonal signaling and reproductive health. Parabens, widely used as preservatives in cosmetics, pharmaceuticals, and foods, have been of recent concern, and are present in over 22,000 cosmetic formulations at concentrations up to 0.8%. Biomonitoring studies have detected parabens in breast tissue, menstrual blood, placental tissue, and ovarian follicular fluid, highlighting potential reproductive disruption. Among these compounds, benzyl paraben (BzP) remains poorly characterized despite its structural similarity to known EDCs such as monobenzyl phthalate (MBzP) and monobenzyl terephthalate (MBzTP). This study evaluated the ovarian toxicity of BzP using an in vitro mouse antral follicle culture model. Follicles were exposed for 96 hours to 0.1–100 µg/mL BzP, reflecting environmentally relevant concentrations. Follicle growth was monitored as a marker of reproductive health, and gene expression was assessed using quantitative PCR to examine pathways involved in steroidogenesis, PPAR signaling, cell cycle regulation, and apoptosis. BzP produced dose-dependent toxicity. At 100 µg/mL, complete follicle death occurred, demonstrating marked cytotoxicity not observed with related compounds. At lower doses, follicles survived but exhibited altered gene expression. *Fabp4*, a marker of PPAR $\gamma$  activation, was significantly upregulated at 10 µg/mL, suggesting activation of PPAR-mediated pathways similar to those induced by phthalates. Overall, these findings indicate that BzP is toxic at high concentrations and may disrupt ovarian function through mechanisms comparable to structurally related EDCs, supporting the need for further evaluation of paraben safety.

 Student Researcher: Arena Chowdhury, Undergraduate

 Faculty Advisor: Genoa Warner

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## #1001 | PLATINUM NANOPARTICLES AS A THERAPEUTIC FOR TRIPLE-NEGATIVE BREAST CANCER

Breast cancer is the most often diagnosed malignancy in women, with triple-negative breast cancer (TNBC) being one of the most aggressive and challenging forms to treat. TNBC lacks the three common receptors, limiting targeted therapy, promoting rapid metastasis, and leaving chemotherapy as the primary treatment. The current treatment involves platinum-based chemotherapy, such as cisplatin, which functions by penetrating the cell, attaching to the DNA, and inducing breaks in the DNA, disabling the cell's ability to proliferate. Nevertheless, it is linked to detrimental effects such as toxicity in the kidneys, heart, and liver. In contrast, nanotechnology has enhanced cancer diagnosis and targeted therapy, with noble metals showing strong potential in nanomedicine. Platinum nanoparticles (PtNPs) have exceptional anticancer activity with little adverse effects on healthy cells. Hence, in this work, PtNPs were developed as an alternative treatment for TNBC. The cell viability study employing PtNPs for TNBC, double-positive breast cancer, cisplatin-resistant uterine sarcoma, and cardiac fibroblasts shows that PtNPs specifically target fast proliferating TNBC without affecting healthy cells. After studying reactive oxidative species (ROS), the mode of action of PtNPs showed that ROS formation does not cause cancer cell death. Additionally, platinum ion release experiments confirmed Pt ion release. In vivo studies showed 100% survival rate in all mouse groups for PtNPs administration, and tumors were successfully established in seven mice (n=7), with the treatment group (n=4) exhibiting a significant reduction in tumor volume compared to the control. In summary, this work provides evidence of a potential new treatment for TNBC.

 Student Researcher: Prova Mehedi Joy, Doctoral




 Faculty Advisor: Kathleen McEnnis

 Materials Science & Mechanical Engineering



## #1002 | TUNING THE REACTIVE SURFACE: HOW MAGNESIUM COMBUSTION PRODUCTS DRIVE RAPID NERVE-AGENT SURROGATE DECOMPOSITION

Rapid decomposition of toxic chemical warfare agents (CWA) into non-toxic compounds is a critical national security priority. Building on our prior evaluation of commercial bulk oxides ( $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ , and  $\text{MgO}$ )- which identified calcined  $\text{MgO}$  as the most effective catalyst for Diisopropyl Methylphosphonate (DIMP) decomposition-this work advances toward realistic “Agent Defeat” scenarios involving high-temperature combustion fireballs. While explosive events generate temperatures sufficient to destroy hazardous chemicals within the fireball, reactions outside this region proceed more slowly and may be enhanced by catalytically active combustion-generated particulates. This study experimentally investigates how metal oxide powders formed during magnesium combustion interact with vapors of CWA simulants. Specifically, we examine the effectiveness of combustion-derived  $\text{MgO}$  in decomposing Diisopropyl methylphosphonate (DIMP), a widely used surrogate for nerve agents. Magnesium powders were burned in an enclosed vessel under varying gas mixtures and fuel/air ratios to produce oxides with distinct physicochemical properties. The resulting smoke contained mixed oxides and residual metal representative of practical combustion environments. Combustion products were characterized and correlated with combustion energetics and formation conditions. Collected powders were packed into a heated laminar flow reactor, where DIMP vapor ( $\sim 3 \mu\text{mol/L}$ ) in air or nitrogen was passed through at 200–350 °C. DIMP decomposition and product formation (e.g., propene) were monitored via FTIR, and post-exposure oxides were analyzed using FTIR-ATR. Results demonstrate that combustion-derived metal oxides significantly enhance DIMP decomposition, with clear correlations between oxide composition, morphology, and catalytic effectiveness.

-  Student Researcher: Swapnil Das, Doctoral
-  Faculty Advisor: Edward Dreyzin
-  Materials Science & Mechanical Engineering

## #1003 | PORTABLE MULTI-TARGET POINT-OF-CARE ELECTROCHEMICAL PLATFORM BASED ON FLOW-THROUGH NANOPOROUS CAPACITIVE MICROFLUIDICS

A portable, automated, and matrix-agnostic diagnostic platform is essential for rapid, decentralized detection of disease biomarkers at the point of care. Conventional laboratory-based diagnostics remain slow, costly, and dependent on trained personnel, underscoring the need for integrated, field-deployable sensing systems. We present a fully automated electrochemical detection platform built around the flow-through Nanoporous Capacitive Electrode microfluidic chip (ESSENCE). This architecture leverages nanoporous capacitive flow through structures to enhance convective transport, reduce diffusion limitations, and increase effective surface area, enabling rapid and sensitive detection in complex biological fluids. The ESSENCE chip employs carbon-based transducer materials functionalized with molecular recognition elements, including aptamers, antibodies, and ssDNA, for selective nucleic acid and protein detection. The platform integrates an onboard battery, Raspberry Pi 5-based automation, a bi-channel potentiostat, and an automated modular microfluidic subsystem with real-time control of valves, flow rate, pressure, and syringe volume. Electrochemical Impedance Spectroscopy (EIS) is used as a label-free detection method, with all fluidic and electrochemical operations synchronized through custom Python control scripts. Using a benchtop prototype, the system detected DNA and RNA targets at 100 pM, demonstrating high selectivity against non-target RNA fragments. The platform further detected the cancer biomarker p53 in artificial urine and human serum at concentrations as low as 1 ng/mL without dilution, demonstrating robust performance in complex matrices. Additional features include multiplexed measurement capability, pogo pin chip interfacing, RMS-based drift minimization, and machine learning-enhanced signal analysis. Together, these advances establish a scalable, field-deployable platform for multi-target, rapid diagnostic testing across diverse biological matrices.

-  Niranjana Haridas Menon, Doctoral
-  Faculty Advisor: Sagnik Basuray
-  Materials Science & Mechanical Engineering



## #1004 | AN ELECTROCHEMICAL SENSOR PLATFORM INCORPORATING A NOVEL MICROFLUIDIC GAS-LIQUID MEMBRANE CONTACTOR AND MACHINE LEARNING-DRIVEN DATA ANALYSIS FOR GAS-PHASE ANALYTE DETECTION

Modern disease diagnostics increasingly emphasize point-of-use (POU) and point-of-care (POC) devices for rapid, non-invasive detection. These include cancer diagnostics, plant disease diagnostics, and antibiotic susceptibility tests. The current gold standard, gas chromatography–mass spectrometry (GC-MS), requires sample collection and laboratory analysis, resulting in delays, increased costs, and analytical errors. Currently, there are no portable, low-cost sensors available in the market that can detect these VOCs with high sensitivity and selectivity in point-of-use(POU) and point-of-care(POC) applications. To address these limitations, this work focused on developing a portable, low-cost microfluidic electrochemical gas sensor platform. Market need was evaluated through the NSF I-Corps program and over 100 stakeholder interviews, identifying lung cancer screening in primary care as a high-priority application, with a target device cost of ~\$5000. To meet this need, this research developed a novel microfluidic electrochemical gas sensor based on gas-liquid membrane contactors that leverages scalable, low-cost manufacturing, namely double-sided adhesive microchannels and physical vapor deposition electrodes. Ionic liquids were selected as suitable candidates as sensing liquid achieving a sensitivity of 0.5 ppm for model gas CO<sub>2</sub>. To enable field deployment, a fully automated, portable prototype integrating fluidics, a potentiostat, a pump, and a Raspberry Pi-based control was developed within a 10 × 10-inch enclosure, achieving performance comparable to that of laboratory systems. Finally, machine learning methods, including support vector regression and physics-informed AI, were applied to directly analyse electrochemical data, eliminating subjective equivalent-circuit modelling and enabling accurate, device-independent prediction. This platform represents a scalable approach toward practical VOC-based diagnostics.

 Student Researcher: Sreerag Kaaliveetil, Doctoral

 Faculty Advisor: Sagnik Basuray

 Materials Science & Mechanical Engineering

## #1005 | GLASS TRANSITION BEHAVIOR OF PLGA NANOPARTICLES IN BIOLOGICAL AND AQUEOUS MEDIA

Poly(D,L-lactic-co-glycolic acid) (PLGA) is a commonly used drug carrier due to its low toxicity, biodegradability, and biocompatibility. Typically, the characterization of PLGA nanoparticles involves determining their particle diameter, size distribution, morphology, and surface charge. However, the significance of the glass transition temperature (T<sub>g</sub>) of nanoparticles is often overlooked, despite T<sub>g</sub> being an important parameter of PLGA nanoparticles impacting the drug release behavior of drug delivery nanoparticles. In particular, the surrounding interface can affect the T<sub>g</sub> of polymeric nanoparticles. As such analysis of PLGA nanoparticles in relevant solutions for drug delivery is important to understand. Nanoparticles in biological fluids form a dynamic “protein corona” that alters their surface characteristics and increases their size. Studies show the T<sub>g</sub> of PS nanoparticles varies with suspension medium—showing strong, weak, or negligible size correlation in water, ionic liquid, and glycerol, respectively—due to differences in interfacial viscosity. While the T<sub>g</sub> of PLGA nanoparticles has not yet been linked to protein corona formation, further research is needed to explore this potential relationship. In this study, model PLGA nanoparticles are prepared and the T<sub>g</sub> of the PLGA nanoparticles suspended in blood plasma, protein solution, water, and PBS is measured using modulated DSC. Release study showed rapid drug release in PBS but markedly suppressed release in plasma, suggesting that interfacial interactions and potential T<sub>g</sub> modulation in protein-rich environments play a critical role in governing drug diffusion. These findings highlight the importance of evaluating T<sub>g</sub> under biologically relevant conditions to better predict in vivo performance of PLGA-based drug delivery systems.

 Student Researcher: Guangliang Liu, Doctoral

 Faculty Advisor: Kathleen McEnnis

 Materials Science & Mechanical Engineering



## #1006 | AL-PVDF COMPOSITE POWDERS PREPARED BY EMULSION ASSISTED MILLING

Despite its widespread use in energetic materials, the effectiveness of aluminum (Al) is inherently limited by the formation of a protective oxide layer on its surface and agglomeration of particles during combustion. One effective strategy to mitigate these limitations and enhance combustion performance is to coat or combine Al particles with fluoropolymers. Among fluoropolymers, polyvinylidene fluoride (PVDF) emerges as a promising material due to its excellent chemical and thermal resistance, durability, and tunable mechanical properties. Several preparation methods have been used to prepare Al-PVDF composite materials. The relevant published reactivity studies primarily employ techniques that characterize bulk oxidation and combustion, relying on thermal analysis and pressure cell-type experiments. Only very limited information is available on the ignition and combustion of individual micron-sized composite Al-PVDF particles. An important experimental challenge is to enable comparison of the same size Al particles with and without PVDF using the same experimental method. Here, this challenge is addressed using emulsion-assisted milling (EAM) to prepare spherical powders with tunable particle sizes and combining Al with 10 wt % PVDF. The prepared composite powders are compared to the same milled powders without PVDF and to atomized Al powders with the same particle sizes. Each powder is fed into a flame, where the particles are ignited and burned. Emission pulses produced by the particles are analyzed to recover the burn time, emission intensity, and temperature. The combustion descriptors obtained from the optical measurements are correlated among themselves and with the powder particle size distributions.

 Student Researcher: Simay Ozsoysal, Doctoral

 Faculty Advisor: Edward Dreyzin

 Materials Science & Mechanical Engineering

## #1007 | MACHINE LEARNING AND TOPOLOGICAL APPROACHES FOR PREDICTING PERMEABILITY OF POROUS MEDIA

Fluid flow through porous media is critical in many industrial and natural processes, such as oil recovery and groundwater filtration. Permeability is a widely-used measure of how easily fluid flows through a porous medium, so developing fast and accurate methods to estimate it is important. In this project, we investigate whether a machine learning (ML) model informed by geometric, topological, and network-based descriptors can accurately predict permeability.

We generate synthetic 3D porous structures using PuMA software and compute their permeability using flow simulations, from which we extract structural descriptors. We also reduce the 3D datasets to pore-scale network representations using PoreSpy, and we utilize computational tools from topological data analysis to calculate topological measures of the porous structures. The combined set of descriptors is used to train the ML model for permeability prediction.

Our results show that the ML model trained on the chosen combination of features is able to predict permeability with high accuracy. In particular, when incorporating topological information, the model consistently performs better than using geometric or network data alone. These findings suggest that topological features can serve as effective descriptors for fluid flow in porous media.

 Student Researchers: Catherin Neena Lalu, Manav Arora, Doctoral

 Faculty Advisor: Lou Kondic

 Materials Science & Mechanical Engineering



## #1008 | FRACTURE MECHANICS OF RARE-EARTH PERMANENT MAGNETS

Rare-earth permanent magnets such as Nd–Fe–B and Sm–Co possess exceptionally high energy density and are indispensable in modern technologies, including electric vehicles, wind turbines, aircraft actuators, and advanced defense systems. However, the intrinsic brittleness of these intermetallic compounds limits their structural reliability and service life, as they are prone to fracture under modest mechanical stresses. During manufacturing, handling, and high-speed operation, the combined action of magnetic and mechanical loads further elevates fracture risk, often resulting in premature failure and disposal of these high-value materials. Therefore, it is imperative to improve fracture resistance and prevent failure in magnetic materials. However, the fracture behavior of these magnets remains insufficiently understood, limiting the development of effective fracture mitigation and management strategies. This project will establish a rigorous, thermodynamically consistent fracture theory for magnetic materials. We will develop a multiphysics continuum framework that integrates couple-stress theory, magnetoelasticity, and cohesive zone modeling to predict fracture under coupled magneto-mechanical loading. Machine learning techniques will be used to analyze simulation data and derive a new fracture criterion for magnets. The resulting magneto-mechanical fracture prediction framework will enhance reliability, prevent premature failure, extend component service life, and help mitigate vulnerabilities in the global rare-earth supply chain.

 Student Researcher: Tareq Bin Taher, Doctoral

 Faculty Advisor: Xing Liu

 Materials Science & Mechanical Engineering

## #1009 | THERMO-MECHANICALLY COUPLED CONSTITUTIVE MODELING OF LARGE-DEFORMATION VISCOELASTIC POLYMERS

Temperature significantly influences the mechanical behavior of viscoelastomeric materials. In this work, we investigate the thermo-mechanically coupled behavior of Santoprene, Styrene-Butadiene Rubber (SBR), and Butyl through a combined experimental and constitutive modeling framework. This work presents a comprehensive experimental program for large-deformation uniaxial tensile testing over a range of temperatures and stretch rates. The experimental results are used to characterize the temperature-dependent, rate-dependent response of these materials. Building upon these observations, we propose a thermo-mechanically coupled constitutive model that captures the effect of temperature variations on large-strain viscoelastic behavior. The model is calibrated using the experimental data and subsequently implemented as a user material subroutine (UMAT) within a finite element framework for validation and predictive simulations.

 Student Researcher: Danial Cheraghali, Doctoral

 Faculty Advisor: Shawn Chester

 Materials Science & Mechanical Engineering



## #1010 | DATA-DRIVEN, VARIATIONALLY CONSISTENT MODEL REDUCTION FOR ACCELERATED SIMULATION OF HAMILTONIAN SYSTEMS

Hamiltonian systems provide a canonical framework for modeling purely conservative dynamics and serve as idealized references for real physical systems. In large-scale engineering applications, reducing model complexity is critical for building computationally efficient digital twins capable of real-time simulation.

Data-driven model reduction techniques are particularly appealing, as they enable the construction of digital twins directly from data, without requiring explicit knowledge of the governing equations. However, conventional reduction approaches often prioritize efficiency over accuracy and robustness, producing reduced-order models (ROMs) that fail to conserve energy or preserve the underlying symplectic structure, limiting their reliability in high-fidelity simulations.

To overcome these limitations, previous works introduced a framework for variationally consistent Hamiltonian ROMs, guaranteeing structure preservation for a given reduced basis. Yet, infinitely many ROMs satisfy the same constraints, raising the question of which is most accurate.

We address this using the NiTROM optimization framework, which identifies optimal ROMs from high-fidelity trajectory data via a non-intrusive optimization on a carefully chosen matrix manifold. With minor modifications, we strongly enforce the desired variational structure and solve the problem efficiently using existing manifold-based descent algorithms with closed-form gradients.

Validated on increasingly complex engineering systems, our approach produces energy-preserving, highly accurate ROMs that form the computational core of digital twins, enabling real-time, reliable simulation and data-driven decision-making for complex engineering applications.

 Student Researcher: Federico Cutolo, Doctoral

 Faculty Advisor: Alberto Padovan

 Materials Science & Mechanical Engineering

## #1011 | ESTIMATION OF 3D WALL SHEAR STRESS IN IN VIVO BLOOD VESSEL SPROUTS USING HIGH-FIDELITY RED BLOOD CELL RESOLVED SIMULATIONS

The sprouting of new blood vessels off existing vessels, or angiogenesis, is ubiquitous at all stages of animal life in both health and disease. Endothelial cells lining blood vessel walls move/reorganize in response to stimuli such as wall shear stress (WSS) exerted by blood flow. While it is well known that microcirculatory hemodynamics influence sprout growth, current understanding is based on idealized geometries and pure plasma flow. To address this gap, we performed 3D red blood cell (RBC) resolved simulations through digitally reconstructed in vivo blood vessel sprouts. The findings reveal physiologically relevant, time-dependent 3D WSS variations along the sprout length due to unsteady host vessel conditions. We identified how RBCs can enter a sprout and exacerbate WSS characteristics influenced by sprout geometry and hemodynamics. In the absence of RBCs in a sprout, WSS magnitudes varied up to 4 dyne/cm<sup>2</sup> along the sprout length, but with RBCs, variations increased to as much as 13 dyne/cm<sup>2</sup>. The findings demonstrate that shorter sprouts experience greater WSS, particularly near the tip; meanwhile, smaller host vessel diameters reduce WSS fluctuations. Altogether, this work presents a new comprehensive estimation of 3D WSS characteristics within in vivo sprouts, offering a foundation for predicting vascular growth.

 Student Researcher: Mir Md Nasim Hossain, Doctoral

 Faculty Advisor: Peter Balogh

 Materials Science & Mechanical Engineering



## #1012 | AGING-RELATED COLLAGEN LOSS PROMOTES FIBROBLAST CONTRACTILITY BUT IMPAIRS WOUND CLOSURE

Fibroblasts, the most abundant cells in connective tissues, play a central role in wound healing through their ability to generate contractile forces. During normal repair, fibroblast-generated forces are transmitted to the extracellular matrix (ECM) and collectively pull wound edges together. Interestingly, aging is associated with increased fibroblast contractility, while wound healing in aged individuals is delayed or impaired. This paradox raises a fundamental question: how can highly contractile cells fail to close a wound despite generating high magnitudes of force? We hypothesized that age-associated reductions in ECM collagen concentration underlie this contradiction. Collagen loss softens the tissue microenvironment, altering both cellular and tissue behavior. To test this, we combined theoretical modeling with in vitro and in vivo experiments to evaluate how collagen depletion affects single-cell contractility and tissue-level force generation, the latter being essential for wound closure. Our results show that decreasing collagen concentration enhances fibroblast contractility. Paradoxically, the same collagen reduction weakens the ECM's ability to transmit these forces across the tissue. Consequently, despite elevated cellular contractility, tissue contraction declines. This uncoupling between cell contractility and tissue force provides a mechanistic explanation for impaired wound closure in aged skin. These findings demonstrate that effective wound healing depends not only on fibroblast contractility but also on the mechanical integrity of the ECM. By shifting the focus from cell-intrinsic aging to the aging microenvironment, this work identifies collagen density as a key regulator of wound healing capacity and suggests that restoring ECM mechanical properties may improve regenerative outcomes in elderly patients.

 Student Researcher: Mohammad Jafari, Doctoral

 Faculty Advisor: Farid Alisafaei

 Materials Science & Mechanical Engineering

## #1013 | THERMO-MARANGONI FLOWS INDUCED BY A HEATED PLATE AT A MOVING CONTACT LINE

The aim of the study is to analyze the flow near the contact line when a heated rectangular plate made up of different material moves vertically in its own plane into a waterbody. The temperature difference between the water and the plate varies as the plate moves at different constant speeds. This temperature difference causes a Thermo-Marangoni flow near the contact line, the magnitude and direction of which depends on the temperature gradient and plate material. The plate speed is between 0.1 mm/s to 2 mm/s which in turn affects the flow speed. The flow field is measured using a MATLAB application-based particle-induced velocimetry technique (PIV). The velocity is obtained on a plane perpendicular to the water surface, and the temperature distribution is measured on the water surface using an infrared thermal camera. The latter is used to estimate the strength of the thermo-Marangoni contribution.

 Student Researcher: Ketan Jawney, Doctoral

 Faculty Advisor: Ian Fischer

 Materials Science & Mechanical Engineering



## #1014 | BUCKLING AND IMPERFECTION SENSITIVITY IN FLUCTUATING FLEXIBLE NANOSTRUCTURES

Thermal fluctuations significantly influence the mechanical behavior of low-dimensional elastic nanostructures due to their small bending stiffness. In this work, we develop a theoretical framework to investigate the buckling behavior of one- and two-dimensional flexible structures namely, elastic rods and crystalline membranes, particularly when they experience large thermal fluctuations. Beginning with a thermally fluctuating elastic rod, we show that classical Euler buckling is recovered when geometric nonlinearities are neglected. Incorporating nonlinearities reveals substantial deviations in force-extension behavior, especially for rods with low bending stiffness. Extending the analysis to crystalline membranes, modeled through a nonlinear von Kármán elasticity of plate, we derive scaling laws for the critical buckling strain as functions of temperature, system size, and further explore their imperfection sensitivity. Our findings show that although imperfections can substantially alter the buckling threshold at zero Kelvin, their influence could be diminished at finite temperatures due to the presence of thermal fluctuations. Further, our results highlight the essential interplay between entropy-driven fluctuations and mechanical instabilities in low-dimensional systems, offering insights relevant to the design of thermally robust nanoscale materials and devices.

 Student Researcher: Md Sojib Kaiser, Doctoral

 Faculty Advisor: Fatemeh Ahmadpoor

 Materials Science & Mechanical Engineering

## #1015 | 3D CELL-RESOLVED COMPUTATIONAL MODELING OF NEUTROPHIL TRANSPORT IN CEREBRAL CAPILLARIES

Transient reductions in capillary blood flow have been observed in cerebral microvascular networks and are increasingly linked to disruptions in tissue perfusion. Neutrophils, due to their larger size and distinct mechanical properties relative to red blood cells (RBCs), can significantly influence local flow behavior in narrow brain capillaries. Understanding how neutrophils are transported through these confined environments is essential for clarifying their impact on microvascular hemodynamics.

This study investigates neutrophil transport within physiologically realistic cerebral microvascular geometries using high-fidelity, cell-resolved computational simulations. By resolving individual RBCs and a circulating neutrophil, we quantify how cell deformability, vessel diameter, hematocrit distribution, and local shear conditions regulate neutrophil positioning, transit dynamics, and flow perturbations. Particular attention is given to near-wall localization, RBC–neutrophil hydrodynamic interactions, and their influence on velocity fields and wall shear stress.

We find that even a single circulating neutrophil measurably alters microvascular flow patterns at the capillary scale. The findings highlight the importance of cell-scale biomechanics and geometric confinement in shaping transport behavior and local perfusion variability. This work contributes to a multiscale understanding of cerebral microcirculation by bridging individual cell dynamics with network-level hemodynamic consequences.

 Student Researcher: Ali Kazempour, Doctoral

 Faculty Advisor: Peter Balogh




 Materials Science & Mechanical Engineering



## #1016 | ROLE OF MECHANICAL STIFFNESS ON MULTIVALENT ADHESION OF FLEXIBLE NANOFILAMENTS ON BIOLOGICAL CELL MEMBRANE

Biological membranes are constantly in contact with various filamentous soft nanostructures that either reside on their surface or are being transported between the cell and its environment. In particular, viral infections are determined by the interaction of viruses (such as filovirus) with cell membranes, membrane protein organization (such as cytoskeletal proteins and actin filament bundles) has been proposed to influence the mechanical properties of lipid membranes, and the adhesion and uptake of filamentous nanoparticles influence their delivery yield. Yet, quantitative studies on the attachment and assembly of these flexible structures in the context of filament-membrane interaction have been scarce. This project investigates the interactions of flexible nanofilaments with biological cells to understand the mechanisms by which flexible nanofilaments adhere to cells and subsequently induce their deformation, a process that can lead to the organization of these nanofilaments and shape transformation of the membrane. Using a hybrid computational framework that combines coarse-grained molecular dynamics and Monte Carlo simulations, we will quantify the specific roles of nanofilament shape and stiffness, cell membrane mechanics, and crowding of nanofilaments on the adhesion strength and the emergent shape of nanofilaments. Knowledge gained from this research will help address the societal needs to understand biophysical principles that govern the attachment and assembly of filoviruses (e.g., Ebola virus) onto the living cells, facilitate the development of next-generation vaccines for a range of diseases, including infectious diseases, and contribute useful scientific knowledge on the interplay among integral membrane proteins and cytoskeletal.

This work is supported by NSF Grant CBET-2327899.

-  Student Researcher: Saba Mirahsani, Doctoral
-  Faculty Advisor: Samaneh Farokhirad
-  Materials Science & Mechanical Engineering




## #1017 | MECHANICAL MEMORY FORMATION IN FIBROBLASTS UNDER DYNAMIC LOADING

Cells in the body continuously sense and respond to mechanical forces from their environment. Fibroblasts, the most abundant cells in connective tissue, are highly sensitive to these forces. To perform their primary functions in wound healing and tissue repair, fibroblasts must become activated, a state characterized by elevated contractility. While activation is essential for wound healing, persistent or excessive activation can lead to pathological outcomes, including fibrosis and scar formation.

Mechanical tension has been identified as a key regulator of fibroblast activation. We previously demonstrated that increasing mechanical tension drives fibroblasts toward an activated phenotype. Furthermore, we showed that long-term static stretch induces mechanical memory, such that cells remain activated even after the external load is removed. This sustained activation suggests that mechanical history can be encoded within the cell through long-lasting cell-matrix feedback mechanisms, increasing the risk of disease progression.

However, in physiological environment, such as heart tissue, fibroblasts are exposed primarily to dynamic, cyclic mechanical loading rather than static stretch. Whether time-varying mechanical cues also induce a mechanical memory remains unknown. In this study, we examine whether fibroblasts subjected to cyclic mechanical loading develop persistent activation after load removal. If mechanical memory forms under dynamic conditions, we aim to identify its molecular signature, including changes in cytoskeletal organization and mechanotransduction pathways. In addition, we investigate whether this mechanically encoded memory can be reversed, restoring cells to a quiescent phenotype.

Understanding how dynamic mechanical environments regulate activation, memory formation, and reversibility may provide strategies for preventing and treating fibrosis.

-  Student Researcher: Fatemeh Ramezani Khozestani, Doctoral
-  Faculty Advisor: Farid Alisafaei
-  Materials Science & Mechanical Engineering



## #1018 | INFLUENCE OF DISSOLVED SOLUTES AND SURFACTANTS ON THE TRANSFER VELOCITY OF CARBON DIOXIDE ACROSS THE AIR–WATER INTERFACE

The exchange of gases, such as carbon dioxide (CO<sub>2</sub>), across the air-water interface is essential for supporting biogeochemical processes in water bodies. In this experimental study, we investigate how CO<sub>2</sub> flux depends on the concentrations of salt and surfactant in the water body. A stagnant film model is used to calculate the gas flux in terms of the transfer velocity. The dependence of the transfer velocity on the salt and surfactant concentrations is investigated. The model assumes that away from the interface, the water and air are well-mixed, and that the transport across a stagnant film is by diffusion. The thickness of the stagnant film depends on the state of mixing on both the air and water sides. The state of mixing of water in our experiments is varied by changing the speed of the magnetic stirrer and by a fan installed on the air side.

 Student Researcher: Shivam Verma, Doctoral

 Faculty Advisor: Pushpendra Singh

 Materials Science & Mechanical Engineering

## #1019 | QMATGPT: GENERATIVE AI-DRIVEN DISCOVERY OF CRYOGENIC ELECTRO-OPTIC QUANTUM MATERIALS

Quantum computing scalability requires electro-optic (EO) materials capable of converting microwave signals from quantum processors into optical signals at cryogenic temperatures (10–20 mK). Current materials, such as LiNbO<sub>3</sub>, face integration and performance limitations, particularly for silicon-based photonic platforms. Identifying new cryogenic EO materials with large Pockels coefficients, low optical/microwave loss, and silicon compatibility remains a major scientific challenge due to the enormous compositional and structural design space of complex oxides. This project develops an AI-driven materials discovery framework to accelerate the identification of next-generation quantum materials. We have constructed a multi-stage computational pipeline: (1) an automated literature Retrieval-Augmented Generation (RAG) system to collect and extract electro-optic data from scientific publications; (2) a multi-agent AI system that parses and structures electro-optic tensors, refractive indices, strain conditions, and temperature-dependent measurements; and (3) a data-engineering framework that organizes these observations into machine-learning-ready datasets. Using curated database entries and selected first-principles DFT/DFPT calculations as ground truth, we are developing predictive machine-learning models for electro-optic properties. The next phase integrates conditional generative AI to propose entirely new perovskite compositions optimized for cryogenic EO performance. This work significantly reduces reliance on brute-force supercomputer simulations and provides a scalable pathway for inverse design of materials for quantum photonics.

 Student Researcher: Raita Rahman, Doctoral

 Faculty Advisor: Dibakar Datta

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## #1020 | ASSESSING FRACTURE RISK OF RUBBER-LIKE MATERIALS UNDER THERMAL AGING

Rubber-like materials are widely used in safety-critical automotive, energy, electrical, and biomedical systems, where their flexibility and fracture resistance are essential for reliable performance. However, exposure to harsh environments combined with mechanical loading during service progressively degrades their structural integrity and causes fracture, leading to economic losses, and safety risks. Among various degradation mechanisms, thermal aging is particularly prevalent, yet its effects on fracture behavior remain insufficiently understood despite extensive studies on deformation response. This project aims to elucidate temperature-dependent fracture mechanisms in rubber-like materials and develop a physics-based predictive framework to quantify fracture behavior under coupled thermal aging and mechanical loading conditions. Temperature exposure alters molecular network architecture through reduced crosslink density and chain scission, resulting in complex and difficult-to-predict fracture responses. To address this challenge, we will integrate experimental characterization with computational modeling to evaluate fracture behavior across a range of aging temperatures and durations, with emphasis on the underlying energetics of the fracture process. The resulting computational framework will enable reliable prediction of fracture under thermal aging conditions. This work will advance durability assessment methodologies and design guidelines, supporting safer and more reliable applications of rubber-like materials in safe-critical, thermally demanding environments in engineering sectors.

 Student Researcher: Sazid Rahman, Doctoral

 Faculty Advisor: Xing Liu

 Materials Science & Mechanical Engineering

## #1021 | BUILDING MY FUTURE BRICK BY BRICK

Over the 2025 summer I had the opportunity to have an internship with Silvi Materials. I was a part of the quality control team, my key role was formulating requested submittals. This experience helped me take what I learned in the classroom and put it into real life, I did not go into my internship blind. I am excited to continue learning and see what the future brings me.

 Student Researcher: Kaylin Rodriguez, Undergraduate

 Faculty Advisor: Mohamed Mahgoub

 Materials Science & Mechanical Engineering

## #1022 | MICROFLUIDIC PRODUCTION OF PLGA NANOPARTICLES FOR DRUG DELIVERY APPLICATIONS



Conventional cancer treatments (ex. chemotherapy) are very limited because they harm both tumors and healthy cells. Meanwhile, a targeted drug delivery system would safely transport drugs through the bloodstream to act only on cancer cells while leaving the rest of the body unharmed. PLGA nanoparticles are ideal drug vehicles because they are long-lasting in the body, cross biological barriers, and break down into biocompatible lactic acid and glycolic acid. However, a significant issue with PLGA vehicles is burst release, where a large amount of drug rapidly leaves the vehicle instead of slow, consistent release at its intended destination. Burst release is related to the glass transition temperature ( $T_g$ ) of the PLGA vehicles.  $T_g$  is the temperature at which a molecule changes from a rigid, “glassy” state to a flexible, rubbery state, causing drug molecules to escape. The relationship between  $T_g$  and particle size in PLGA is under-researched. To close this gap, we produce PLGA nanoparticles of various diameters and measure the resulting  $T_g$ . We chose a microfluidics system because, unlike traditional nanoparticle production methods, it provides both constant particle sizes and surfactant levels. Testing various microfluidics parameters (ex. PLGA concentration, flow rates) allows us to expand the size range of nanoparticles produced. Understanding the relationship between  $T_g$  and nanoparticle size is crucial information for designing PLGA nanoparticles that control for burst release. This advancement would be a critical step in producing functional targeted drug delivery systems, with the potential to transform medicine, pharmacology, and cancer therapy.

 **Student Researchers:** Konstantina Alamani, Nethra Madhav, Undergraduate

 **Faculty Advisor:** Kathleen McEnnis

 **Materials Science & Mechanical Engineering**

## #1023 | ENHANCING THE PRINTABILITY OF LOW-VISCOSITY HYDROGELS FOR SOFT TISSUE FABRICATION

In the field of tissue engineering and regenerative medicine, 3D bioprinting has gained particular interest in its ability to fabricate tissues and organs for treatment. This technology prints out hydrogels which are soft, water-based biomaterials that serve as the scaffold for cells to grow on. Previous literature reveals how soft scaffolds, due to their low viscosity, have poor printability: the ability for the hydrogel to be correctly deposited and to maintain their desired shape. As such, this study aims to use gelatin as a thickening agent to improve the printability of hydrogels composed of low viscosity methacrylated alginate (MeAlg) and methacrylated hyaluronic acid (MeHA). Various concentrations of gelatin and biomaterial were combined and rheological testing for viscosity, crosslinking kinetics, and stiffnesses was used to elucidate the ideal formulation for optimal printability. In addition, a standard line test for printability analysis was conducted and a combination of 3% MeAlg with 5% gelatin and 1% MeHA with 3% gelatin was determined to be the most ideal hydrogel formulation for each biomaterial. After crosslinking, the gelatin was removed from the hydrogel by submerging it in PBS at 37°Celsius to decrease the scaffold’s mechanical stiffness. Future work will include a cell study to test for cell viability, proliferation, and differentiation into the desired tissue type. Success in this project will elucidate alternative hydrogel formulations for cell types that favor softer scaffolds. This technique can also be applied to different biomaterials besides MeAlg and MeHA, opening avenues for further possibilities and innovation.

 **Student Researcher:** Justin Chen, Undergraduate

 **Faculty Advisor:** Murat Guvendiren

 **Materials Science & Mechanical Engineering**



## #1024 | ANALYZING POLYMER NANOPARTICLES IN BLOOD PLASMA FOR DRUG DELIVERY APPLICATIONS

Chemotherapy is a type of cancer treatment that can effectively target and kill cancerous cells, but negatively affects healthy cells, leading to undesirable side effects in patients. To improve these outcomes, targeted drug delivery is essential. Nanoparticles (NPs) provide an effective solution, controlling drug release at specific sites to reduce off-target toxicity.

However, while NPs are a great tool for targeted therapies, they still need to be researched further, specifically within biological systems. A common occurrence when NPs are introduced into biological systems is particle aggregation, which is due to nanoparticles interacting with the many proteins and other molecules found within the blood plasma. This can lead to the formation of a protein corona (PC) surrounding the NP, which can compromise drug efficacy and patient safety.

The purpose of this research is to study the interactions that occur between polymer NPs and blood plasma using nanoparticle tracking analysis (NTA). The NTA visualizes and tracks particle movement in a specific solution via laser light scattering. Our lab developed a novel technique to analyze NPs directly in pure blood plasma, providing unique insights into protein corona formation and particle aggregation.

The aim of this research project is to understand how polymer NPs interact with goat and bovine blood plasma and Alsever's and sodium citrate anticoagulants in various combinations and dilutions to observe its effects on PC formation. The goal is to see how this information can translate to creating an effective targeted drug delivery mechanism to be used in the human body.

 Student Researcher: Priyanka Sunkara, Undergraduate

 Faculty Advisor: Kathleen McEnnis

 Materials Science & Mechanical Engineering

## #1025 | EXPERIMENTAL FULL-FIELD ANALYSIS OF MONOTONIC FRACTURE IN ELASTOMERS

The distinctive mechanical behavior of elastomers enables widespread use across engineering systems and everyday technologies. Their ability to endure large, nonlinear deformations makes them highly desirable, but they are also susceptible to damage/fracture. Unexpected fractures can lead to catastrophic system failure. Thus, it is critical to predict fracture behavior at varying temperatures in elastomeric materials throughout their service life to mitigate unexpected failures. In response to this challenge, single-edge notched monotonic stretch measurements during crack initiation and propagation provide experimentally validated datasets for analysis of fracture behavior. These validated datasets support diverse applications ranging from forward engineering to ongoing research. The quantified mechanical response supports predictive modeling and design optimization while the established microstructure-mechanical relationships enable evaluation and prediction of newly developed materials. To understand fracture behavior, we investigate crack propagation in Santoprene, Styrene-Butadiene Rubber (SBR), and Butyl under varying thermal conditions. The fracture behavior of these materials is tested by conducting full-field strain measurements, load-unload testing, and load-to-failure response. The experimental results demonstrate that strain-to-failure and stress-to-failure decrease as temperature increases. These findings support accurate design engineering for elastomeric parts.

 Student Researcher: Alexa Staab, Undergraduate

 Faculty Advisor: Shawn Chester

 Materials Science & Mechanical Engineering



## #1026 | MULTIPHYSICS MODELING OF ARCHITECTED METAMATERIAL IN THERMAL MANAGEMENT SYSTEMS

Recent advances in additive manufacturing have enabled the fabrication of architected materials with geometric complexity unattainable by conventional manufacturing, opening new opportunities for high-performance thermal-structural components. Triply periodic minimal surface (TPMS) metamaterials, particularly Gyroid-based architectures, offer high surface-area-to-volume ratios and favorable mechanical behavior, making them attractive for applications requiring efficient heat transfer within load-bearing structures. Despite these advantages, the deployment of TPMS architecture remains limited by unreliable predictive models under coupled thermo-mechanical loading, where thermal gradients, cyclic stresses, and manufacturing-induced imperfections govern failure. This research investigates the influence of TPMS architecture on thermal performance and mechanical resilience and develops an experimentally informed predictive framework to capture coupled thermal-mechanical response and damage initiation. Parametric unit-cell geometries are generated using nTopology and evaluated through coupled thermal-structural simulations in COMSOL Multiphysics, with additive manufacturing-relevant imperfections explicitly incorporated. Model predictions are assessed against established scaling relationships and experimental trends to enable reliable performance evaluation. By linking micro-scale geometric defects to macro-scale thermo-mechanical behavior, this work establishes a foundation for the robust design of TPMS-based thermal management systems across aerospace, energy, and biomedical applications.

 Student Researcher: Andre Cordova, Undergraduate

 Faculty Advisor: Xing Liu

 Materials Science & Mechanical Engineering

## #1027 | CAPACITIVE SENSOR FOR PFAS REAL-TIME DETECTION IN WATER

As of a 2015 study, 97% of Americans carry PFAS (per/polyfluoroalkyl) substances in their blood. Often consumed through beverages, contamination increases the chances of infertility, cancer and accelerated puberty. Once ingested, PFOA (perfluorooctanoic acid) has a half-life of at least 2 years. Traditional PFOA detection relies on large, slow, inaccessible, and expensive laboratory setups.

A novel capacitive sensor achieved detection of PFOA in deionized water at the part-per-trillion (ppt) range of concentration. Signal strength is directly proportional to PFOA levels. The sensor features a gold micro-electrode functionalized with an electroactive binding composite. PFOA binding to the sensor surface shifts charges and alters surface properties, resulting in measurable changes in capacitance. Tests in deionized water demonstrated real-time detection at concentrations of 4ppt.

The sensor presents a compact, scalable alternative to mass spectroscopy (traditional detection). Consequently, equipping water treatment facilities with faster feedback. Future research aims to enhance sensitivity into the parts per quadrillion range and reduce interference, thus advancing efforts to monitor and eliminate PFAS.

 Student Researcher: Chadley Gede, Undergraduate

 Faculty Advisor: Eon Soo Lee

 Materials Science & Mechanical Engineering



## #1028 | THERMAL RECOVERY OF THE MULLINS EFFECT IN FILLED RUBBERS: EXPERIMENTS AND MODELING

Filled rubbers are a ubiquitous class of engineering materials with many attractive engineering properties. They experience a phenomenon known as the Mullins effect, characterized by a loss in strength and stiffness after an initial deformation. However, this strength and stiffness can be recovered, in a process which is generally thermally activated, and typically known as Mullins recovery. Few models exist to account for the Mullins effect after recovery with most focusing on experimental aspects in a limited range of conditions. This work focuses on creating a comprehensive experimental data set and a continuum model to describe both Mullins effect and thermally activated Mullins recovery. The model is calibrated to the data, and implemented as a user material subroutine in a finite element package to show its application.

 Student Researcher: Mark Nyeugen, Undergraduate

 Faculty Advisor: Shawn Chester

 Materials Science & Mechanical Engineering

## #1029 | SKIN-CONFORMAL TACTILE SENSOR ARRAY FOR ADVANCED HUMAN-MACHINE INTERACTION

Seamless human-machine interfaces (HMIs) require electronic systems capable of sensing and interpreting mechanical stimuli. In advanced HMIs, flexible pressure sensors convert force into electrical signals for tactile feedback. For wearable and soft robotic applications, these sensors must conform to dynamic surfaces while maintaining high sensitivity and stability. Additionally, array-level patternability is essential for spatial pressure mapping and application-specific designs. However, integrating sensitivity, stretchability, and customizable array architectures within a single platform remains challenging, as many existing systems are rigid, bulky, or difficult to pattern, limiting their application in next-generation wearable and robotic technologies. To overcome these limitations, we developed a fully integrated pressure sensor array that combines flexibility, stretchability, and patternability within a compact structure. The device consists of a skin-mountable array of sensing units composed of compliant elastomeric layers, liquid metal oxidized eutectic gallium-indium (OGaIn) electrodes for strain-resilient electrical interconnection, and a carbon nanotube (CNT) piezoresistive interlayer. The sensor exhibits a wide working range of 0–1100 kPa, with sensitivities of  $0.008 \text{ kPa}^{-1}$ ,  $0.004 \text{ kPa}^{-1}$ , and  $0.002 \text{ kPa}^{-1}$  across 0–180, 180–480, and 480–1100 kPa, respectively. Owing to this sensitivity, it also shows clear responses to gentle finger touch, indicating its capability to detect subtle tactile stimuli. High-resolution array geometries are enabled through vacuum filtration-based CNT patterning combined with precision laser cutting. This patternable and flexible sensor array establishes a lightweight, conformable, and mechanically robust tactile platform that advances skin-integrated HMI technologies, enabling intuitive, distributed, and seamlessly integrated human-robot interaction.

 Student Researcher: Iniobong Ofonime, Undergraduate

 Faculty Advisor: Lin Dong

 Materials Science & Mechanical Engineering



## #1030 | A VIRTUAL REALITY-BASED EMG PLATFORM FOR PRECISION PROSTHETIC FITTING

Despite decades of innovation in prosthetic hardware, upper-limb prosthesis abandonment remains unacceptably high. Many users discontinue their devices not because of mechanical limitations, but due to unreliable myoelectric control and rapid muscle fatigue. Yet prosthetic fitting still relies largely on subjective assessment and trial-and-error selection of residual muscle sites, with no quantitative method to predict control stability or long-term performance. This fundamental gap undermines functional outcomes and contributes directly to device rejection. To address this problem, we developed a data-driven electromyography (EMG) evaluation platform integrated with an immersive virtual task environment to objectively identify optimal muscle control sites and assess functional capability in amputee patients. In this system, participants first perform tasks in a virtual environment using their intact limb to establish baseline physiological signals, after which the same procedures are conducted with the amputated limb to enable direct comparison of muscle activation and clenching performance. This comparative framework transforms prosthetic evaluation into a measurable, performance-based process. In preliminary trials, the amputated limb generated higher peak amplitudes of 280–320 mV with RMS values of 100–220 mV. After approximately 40 seconds, a noticeable decline in RMS magnitude occurred, indicating earlier fatigue onset compared to the intact arm. These measurements provide quantitative indicators of fatigue and energy expenditure during interaction with the system. By replacing subjective fitting with quantitative optimization, this platform establishes a new paradigm for precision myoelectric prosthetic design, one that has the potential to increase control reliability, improve rehabilitation outcomes, and fundamentally reduce prosthesis abandonment.

 Student Researchers: Yogev Rikin, Natalie Kiwanian, Undergraduate

 Faculty Advisor: Lin Dong

 Materials Science & Mechanical Engineering

## #1031 | A PREDICTIVE FRAMEWORK FOR CRACK ARREST FRACTURE TOUGHNESS IN STRUCTURAL MATERIALS

The aging and accidental damage of structural materials can lead to catastrophic failure in large-scale systems, such as ships and aerospace components. To mitigate this risk, crack arrest fracture toughness,  $K_{ca}$ , which characterizes a material's ability to halt a rapidly propagating crack, serves as a critical last-resort safeguard against structural failure and must be explicitly considered in material design and risk assessment. However, the current understanding of crack arrest toughness remains limited due to the complexity and high cost of crack arrest testing, even though decades of experimental data exist across the literature in fragmented and inconsistent formats. In this project, we consolidate historical  $K_{ca}$  data for structural steels into a unified dataset and develop a machine-learning-based predictive framework for  $K_{ca}$ . The dataset comprises chemical composition, temperature, processing condition, test method, and corresponding  $K_{ca}$  values. Feature-importance analyses are conducted to identify the dominant factors governing  $K_{ca}$ . A composite neural network architecture integrating classification and regression components is employed to establish a quantitative relationship between  $K_{ca}$  and the identified key factors. Partial dependence analysis is performed to interpret this complex relationship, and the underlying physics are rationalized. We further deploy the composite neural network as a web-based, open-access predictive tool to support engineering applications. More broadly, this work illustrates how systematic mining of historical scientific literature, coupled with machine learning, can advance fracture mechanics and materials design.

 Student Researcher: Gabriel Correa, Undergraduate

 Faculty Advisor: Xing Liu

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