# VINSE

## 14th Annual Undergraduate Research Symposium

July 31, 2025 | 1:30 – 3:30PM
Engineering Science Building

VINSE

VANDERBILT UNIVERSITY

Vanderbilt Institute of Nanoscale Science and Engineering
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# Welcome to the 2025 Undergraduate Research Symposium!

Dear Students, Faculty, Mentors, and Friends,

Thank you for joining us at the 14th Undergraduate Research Symposium!

Today, students who participated in 10-week summer research programs present the results of their work and share what they have accomplished over the summer.

The participating programs are committed to providing undergraduates with meaningful, hands-on research experiences that support their growth and prepare them for future study and careers in nanoscience and engineering.

As Director of the VINSE NSF-REU, I'm honored to support this work and look forward to welcoming the next group of students in the coming year.

Thank you for being here - hope you enjoy the presentations.

All the best!

Josh Caldwell

# 14th Annual Undergraduate Research Symposium

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## 1 | Maggie Ferguson | VINSE NSF - REU

**Ligand Manipulation in the Phase Control of Manganese Sulfide Nanocrystals**

**Maggie Ferguson**[1,3], Elizabeth Hays[2,3], Blake Catlett[4], Janet Macdonald[2,3,4]

*[1]University of Virginia, Department of Materials Science and Engineering, Charlottesville, VA 22903 [2]Vanderbilt University, Department of Interdisciplinary Materials Science, Nashville, TN 37235*

*[3]Vanderbilt Institute for Nanoscale Science and Engineering, Nashville, TN 37235*

*[4]Vanderbilt University, Department of Chemistry, Nashville, TN 37235*

The crystalline phase of metal chalcogenide nanoparticles is critical in accessing desirable electrical, magnetic, and optical properties. Common methods of controlling phase are through the manipulation of reaction temperature, precursor reactivity, solvent, and ligand. Specifically, previous work in the Macdonald lab indicates that altering ligand carbon chain length can influence nanoparticle growth kinetics, thus influencing the resulting phase. These results indicate that a larger ligand shell surrounding a nanoparticle slows the kinetics of nanoparticle growth, allowing for increased metastability. In the manganese sulfide system, four natural polymorphs exist. Under investigation in this research are two of these four: the $\alpha$ phase, commonly referred to as Alabandite; and the $\gamma$ phase, known as Rambergite. The $\alpha$-MnS phase crystallizes in a cubic close packing (CCP) sulfur arrangement with manganese atoms occupying octahedral interstitial holes and is regarded as the thermodynamic phase. The $\gamma$-MnS phase is the most naturally abundant metastable phase and crystallizes roughly into a hexagonal close packed (HCP) arrangement of sulfur atoms with manganese atoms occupying tetrahedral interstitial holes. The study at hand focuses on the effects of altering manganese(II) carboxylate carbon chain lengths in the colloidal synthesis of $\alpha$-MnS and $\gamma$-MnS phase mixtures.

**Bio.** Maggie Ferguson is a rising fourth-year undergraduate studying Materials Science and Engineering with a minor in Spanish at the University of Virginia in Charlottesville, Virginia. Maggie is involved with the UVA chapter and national organization of Material Advantage and has served on the Materials Science & Engineering Diversity, Equity, and Inclusion committee as an undergraduate representative. Her research this summer in the Macdonald nanoparticle synthesis group was funded through the National Science Foundation's Research Experience for Undergraduates (REU) program at the Vanderbilt Institute for Nanoscale Science and Engineering.

## 2 | Vanessa Omatu | Vanderbilt VIBES

**High-wavenumber Raman spectroscopy for the nondestructive assessment of fluid viscosity**

**Vanessa Omatu[1,2],** Alec B. Walter[1,2], Anita Jansen-Mahadevan[1,2,3]
*[1]Department of Biomedical Engineering, Vanderbilt University, Nashville, TN*
*[2]Biophotonics Center, Vanderbilt University, Nashville, TN, USA*
*[3]Department of Surgery, Vanderbilt University Medical Center, Nashville, TN, USA*

Viscosity alterations in biological fluids such as mucus, saliva, and blood serum often serve as critical indicators of pathological conditions. Despite its diagnostic potential, viscosity measurement remains underutilized clinically due to the destructive nature and substantial sample volume requirements of conventional rheological techniques. This project explores the feasibility of employing high-wavenumber Raman spectroscopy as a non-destructive method for assessing the viscosity of biological fluids. Raman spectroscopy is an optical technique that utilizes inelastic light scattering to provide molecular-level insights into the chemical composition and structural characteristics of samples. For this preliminary study, solutions of bovine serum albumin (BSA), porcine mucin, and their combinations were prepared in deionized water across a range of concentrations. The viscosities used for reference were measured using a RheoSense MicroVISC portable viscometer for each solution. The Raman spectra were acquired for each sample using a Raman spectrometer, particularly focusing on the high-wavenumber region as it contains details on where water bonding and protein structural information are typically observed. As expected, the measured viscosity increased with higher solute concentrations, with mucin solutions exhibiting greater viscosities than BSA. Analysis of high-wavenumber Raman spectral features demonstrated strong correlations with the measured viscosity trends, with the combined BSA+mucin samples exhibiting a strong relationship matching the effects of both additives. These findings indicate that specific Raman spectral markers reliably reflect the viscoelastic properties of the solutions. From these results we can conclude that high-wavenumber Raman Spectroscopy has the potential to assess the viscosity of biological fluids non-destructively.

**Bio.** Vanessa Omatu is a rising Senior at Vanderbilt University, majoring in Biomedical Engineering with minors in physics and nanoscience. She has a strong interest in biomedical optics, focusing on the characterization of biological materials using spectroscopic techniques. During the summer research program, Vanessa contributed to a project exploring the relationship between viscosity and Raman spectral bonds in protein solutions. Vanessa is also actively involved in Vanderbilt 's Biomedical Engineering Society as vice president, and a member of the VBC newsletter team.

## 3 | Kevin Chen | VUSE Summer Research Program

**Neuro-Symbolic Rubik's Cube Solver**

**Kevin Chen**[1], Taylor Johnson[2]
[1]*Computer Science, Vanderbilt University*
[2]*Computer Science, Vanderbilt University*

Multimodal large language models (LLMs), like Vision language models (VLMs), have been proven to be powerful reasoning tools that can perform complicated tasks such as text generation, video and image reasoning, and code generation. However, LLMs have been shown to struggle with more trivial tasks like visual reasoning and the visual processing of puzzles. In this work, we propose the task of processing a visual input of two images representing all faces of a scrambled Rubik's cube and correctly representing its state in a string format that can be compatible with already existing algorithms to solve the scrambled Rubik's cube and output a set of moves to solve the cube. Our approach is to use edge detection combined with a neural network to detect faces and other smaller pieces like corner and edge pieces, then use the processed information to reconstruct its state through a recursive backtracking solution. We show that compared to state-of-the-art LLMs that fail to reason and reconstruct the state, our recursive backtracking solution properly reconstructs the state given enough relevant information and constraints identified by the neural network. Our project shows the potential of Neuro-symbolic AI outperforming LLMs in visual reasoning tasks like identifying the state of a puzzle like a Rubik's Cube.


**Bio.** Kevin Chen is a Junior at Vanderbilt University majoring in Computer Science, Mathematics, and Viola performance. Kevin is currently researching the capabilities of Neuro-Symbolic AI with Taylor Johnson under the Institute for Software Integrated Studies, his focus is researching ways that Nuero-Symbolic AI can outperform multimodal Large Language Models, providing alternative visual reasoning approaches.

## 4 | Emma Conley | Vanderbilt University SMART

**Magnetically Actuated Skin Patch for Distributed Stiffness Sensing**

**Emma Conley**[1], Peixi Xuan[3], Ruijian Ge[1], Xiaoguang Dong[1,2,3]
*[1] Department of Mechanical Engineering, Vanderbilt University, TN 37212, US*
*[2] Department of Biomedical Engineering, Vanderbilt University, TN 37212, US*
*[3] Department of Electrical and Computer Engineering, Vanderbilt University, TN 37212, US*

Monitoring biomechanical properties of biological tissues can provide critical information about pathological conditions. Quantitative monitoring of tissue stiffness shows potential for early detection, diagnosis, and continuous observation of diseases such as fibrosis, cancer, systemic sclerosis, and edema. In oncology, elevated stiffness is correlated to tumor growth and can aid in detecting positive surgical margins as well as longitudinally monitoring cancer patients. Existing commercial devices can quantify skin stiffness but are lacking in spatiotemporal detection, resolution, portability, and feasibility for long-term use. To tackle this challenge, we propose a minimally invasive, magnetically actuated wearable device for measuring the distributed stiffness of human skin tissues. The design features three evenly spaced magnetic cantilever beams, each actuated by an external magnet and equipped with a probe for palpating soft tissues. Localized stiffness underneath each probe is calculated based on the known force applied by the external magnet and the induced material deformation measured by motion tracking. The device operates continuously using a linear actuator to apply and relieve force from the actuating magnet. The device is tested on soft polymers with known elastic moduli ranging from 5.3 kPa to 37.6 kPa to examine the relationship between material elasticity and probe deformation. Preliminary results show a clear relationship between the elastic modulus of a soft substrate and probe deformation using cameras and magnetic actuation. Future work will focus on verifying the cantilever beams' independence of motion on a heterogeneous skin patch, supporting the use of the device for localized sensing in clinical applications.

**Bio.** Emma Conley is a rising sophomore undergraduate student at Vanderbilt University where she is pursuing a BS degree in Mechanical Engineering with a minor in Digital Fabrication. She joined Dr. Xiaoguang Dong's research lab in June 2025 with a strong interest in medical robotics. Over the summer, she has been focusing on the magnetically actuated skin patch for distributed stiffness sensing while also assisting in developing a pH sensor for smart bone implants.

## 5 | Kalyn Day & Battulga Purev | VUSE Summer Research Prog.

**An Investigation of Single Event Upsets in Multi-Level-Cell NAND Flash Memory**

**Kalyn J. Day[1], Battulga P. Purev[1],** Estefania Esquer[2], Brian D. Sierawski[3]
*[1]Undergraduate student at Vanderbilt University*
*[2]Graduate student at Vanderbilt University*
*[3]Vanderbilt University – Institute of Defense and Space Electronics*

This research investigates single-event upsets (SEUs) in multi-level-cell (MLC) NAND flash memory devices exposed to radiation. The purpose of the study is to evaluate SEU behavior in MLC NAND flash memory and to develop a test method for this memory type. Although SEU rate prediction models exist, they are often based on comparisons with static random-access memories, which differ in structure and behavior. Due to the operation of these devices - which store multiple logical bits in a single physical cell using various levels of stored charge - errors were anticipated in states representing intermediate or neutral levels. This investigation provides insight into the reliability of MLC NAND flash memories in radiation-prone environments.

To conduct this investigation, a Micron 64 GB MLC NAND flash memory chip was decapsulated to expose the internal die for radiation testing. A prototyping board connects the memory chip, mounted in a 48-pin socket, with a Teensy 4.0 microcontroller. Custom C code was developed to execute read, write, and erase operations on the memory. A test program was constructed to scan through the memory and identify bit flips from single event upsets.

Radiation tests were performed with an Americium-241 source positioned above the exposed die. Results of the radiation exposures are summarized. This work supports future development of more accurate upset models and test methods tailored to complex memory structures.

**Bio.** Kalyn Day is an incoming junior from Land O' Lakes, Florida. She is studying Electrical and Computer Engineering with a minor in Computer Science at Vanderbilt University. Within computer engineering, her interests lie in radiation effects in microelectronics and designing electrical systems for space applications. Kalyn has completed previous undergraduate research work with the Vanderbilt Institute of Space and Defense Electronics on their Laboratory Radiation Test Training Simulator.

**Bio.** Battulga Purev is a rising junior from Arlington, Virginia. He is studying electrical and computer engineering at Vanderbilt University. His interest focuses on radiation effects on microelectronic devices and developing radiation-hardened electronics for defense and space industries. He is currently conducting undergraduate research on single-event upsets in NAND flash memory under the supervision of Dr. Sierawski. Recently, he participated in the Nuclear and Space Radiation Effects Conference (NSREC) held in Nashville, TN.

## 6 | Juliette Lipari | VINSE Tech Crew

**Characterization of Deposition Parameters in Sputtered Metal Thin Films**

**Juliette Lipari**[1,2], Megan Dernberger[2]
[1]*Department of Computer Science, Vanderbilt University*
[2]*Vanderbilt Institute of Nanoscale Science and Engineering, Vanderbilt University*

Thin film sputter deposition is a widely used method for applying thin coatings to substrates. This process uses ions in plasma to eject atoms from a target material, which then form a film on the substrate surface. These films are essential components in devices such as electronic circuits, sensors, and optics. Although the AJA Sputter Deposition System in the VINSE cleanroom has a repository of recipes, many were created over five years ago and may no longer yield accurate results. This project examines how power source type (RF or DC), power level, sample plate rotation speed, and sample z-axis height affect the deposition rate and resistivity of sputtered aluminum, copper, and tungsten films. DC (direct current) power provides a constant voltage and is ideal for conductive materials, while RF (radio frequency) power alternates rapidly and works for both conductive and insulating targets. To assess spatial uniformity, three silicon chip substrates were placed at multiple radii on the sample plate for each run. Results show a strong linear relationship between power and deposition rate for all tested metals. DC yielded 20–35% higher rates than RF for aluminum, while RF produced films with better spatial uniformity and more consistent electrical properties at higher powers—key factors for electronic applications. For tungsten, 50 rpm rotation gave the most uniform deposition compared to no rotation and 90 rpm. A z-axis height of 110 mm yielded the most consistent copper deposition across the tested range. Additionally, tungsten's measured rate differed by 14.2% from the existing rate, underscoring the need for periodic recalibration of the recipe repository. This study provides updated guidance for characterizing sputter deposition parameters in contemporary microelectronics and thin-film device fabrication.

**Bio**. Juliette Lipari is a rising sophomore at Vanderbilt University majoring in Computer Science and Applied Mathematics with a minor in Engineering Management. She joined the VINSE Tech Crew in the summer of 2025 and focuses her research on sputter deposition parameters. Outside the lab, Juliette is a Product Space Fellow, serves on the Professional Development Committee for the Society of Women Engineers, and holds the role of Service Chair for Theta Tau, a professional engineering fraternity.

## 7 | Sarah Breslow | Chemical Biology NSF-REU

**Qualitative Lipid Profiling and Quality Control Monitoring of Human Plasma**

**Sarah E. Breslow**[1,2], Henry A. Adeola[1], Renã A.S. Robinson[1]
*[1]Department of Chemistry, Vanderbilt University, Nashville, TN 37235*
*[2]Department of Chemistry, Fairfield University, Fairfield, CT 06824*

Lipidomics is a rapidly growing field supported by recent advancements in mass spectrometry (MS) and its ability to identify disease biomarkers. However, embedding quality control (QC) monitoring into MS lipidomics workflows is crucial to ensure integrity and reproducibility of data and to reduce variability in large-scale studies. Despite advancements in lipidomics QC, the lack of universal protocol requires each laboratory to individually develop and optimize QC methods. In this study, a tandem mass spectrometry (MS/MS)-based approach was used to analyze serially diluted lipids extracted *via* the Bligh-Dyer method from plasma standards and a QC pool of ~ 100 patient plasma samples. Samples were spiked with internal lipid standards. A targeted lipidomics approach using a multiple reaction monitoring method was used to analyze 1150 lipids. Reproducibility was evaluated using analyte peak areas obtained from 60 repeated injections of the QC pool sample across four days. We observed a linear relationship between concentration and the peak area of diacylglycerol, the most represented IS analyte in the plasma standard, but not for IS such as phosphatidylcholine and monoacylglycerol. We report 637 and 550 identified and quantifiable lipid species in the plasma standards, respectively; while 521 and 443 identified and quantifiable lipid species were found in the QC pool sample, respectively. Lysophosphatidylcholine (LPC) was the best represented IS in the QC pool. In this presentation, we will report interday and intraday coefficients of variation (%CV) for lipid standards. Our preliminary findings suggest that our method effectively identifies lipid species in blood plasma; however, significant variance within the QC pool over time emphasizes the necessity for thorough QC development and optimization in lipidomics.

**Bio.** Sarah is a rising senior chemistry major with minors in mathematics, health studies, and classical studies from Fairfield University. She conducts research at Fairfield where she studies Solid-Phase Peptide Synthesis of peptides containing α,α-dialkylated amino acid residues. She and her research team published this work to the Journal of Visualized Experiments. Additionally, she received the American Chemical Society Award in Undergraduate Analytical Chemistry. After graduation, she plans to pursue a Ph.D. in chemistry.

## 8 | Taylor Donen | VUSE Summer Research Program

**ITO/Pt/ITO Stacks for High-Performance and Transparent Neural Probes**

**Taylor Donen**[1], Grace Adams[2], Daniel Gonzales[2,3]
[1]*Rose-Hulman Institute of Technology: Department of Biomedical Engineering*
[2]*Vanderbilt University: Department of Biomedical Engineering*
[3]*Vanderbilt University: Vanderbilt Brain Institute*

Neural interfaces that allow for simultaneous neurophysiology and optical imaging can advance our understanding of neural circuit mechanisms by providing both millisecond-scale neural activity and cell-specific mapping. However, conventional silicon-based microelectrode arrays are opaque and therefore incompatible with imaging methods such as two-photon microscopy. A technological need exists for a transparent and conductive material for these implantable probes. Although indium-tin oxide (ITO) is an attractive material for this purpose due to its high conductivity, optical transparency, and ease of fabrication, ITO conductivity is less superior compared to traditional metals and known to be brittle and crack during implantation. Here, we fabricate a composite material to maintain a high optical transparency while increasing ITO reliability using a "stack" approach: two 50 nm layers of transparent ITO surrounding an ultra-thin layer of platinum (Pt). Silicon wafers and glass slides were coated with transparent polymer Parylene C and patterned with electrode traces using photolithography. The ITO/Pt/ITO stack was deposited onto wafers with sputter deposition, and a second layer of Parylene C was deposited and selectively etched to expose the electrodes and contacts. Pt deposition power varied from 30W to 100W (1 to 5 nm) across different samples. After transparency testing, all stacks had ideal transmittances of >50% over the relevant 300-1100 nm wavelength range, with thinner Pt layers providing the highest transparency. We also show that the ITO/Pt/ITO stack has improved electrochemical impedance performance when compared to ITO-only electrodes. The properties of this composite material allow for the actualization of fully transparent neural probes that will enable precise brain mapping and improve solutions for neurological conditions.

**Bio.** Taylor Donen is a rising junior at Rose-Hulman Institute of Technology pursuing a double major in Biomedical Engineering and Biomathematics. Her prior research experience includes characterizing bioglass-based cement at Rose-Hulman and 3D-bioprinting fungal fibers at University of Colorado Boulder. At Rose-Hulman, Taylor serves as president of the Biomedical Engineering Society and leads the STEM Outreach Committee as part of the Noblitt Scholars Program. In the future, she plans to pursue her Ph.D. and continue neural engineering research to help improve treatments for neurological conditions.

## 9 | Jaycie Nguyen | VU Undergraduate Summer Research

**Enhancing Concept Drift Detection in Network-Based Malware Classification Using ADWIN with Performance-Aware Retraining and Statistical Validation**

**Jaycie Nguyen**[1], Taylor T. Johnson[1]
[1]*Department of Computer Science, Vanderbilt University*

This project addresses the challenge of concept drift in machine learning models used for classifying network traffic. Concept drift occurs when the patterns a model learns during training begin to change over time, often due to evolving behaviors in the data. In cybersecurity, this becomes especially important, as attacks can shift in structure, making older models less reliable over time. To explore this problem, this study uses the CICIDS2017 dataset, with a focus on detecting Distributed Denial of Service (DDoS) and PortScan attacks. The approach involves using ADWIN, an adaptive windowing method that tracks changes in model accuracy over time. When the model's accuracy falls below a set threshold, it is retrained on the most recent batch of data to recover performance. A Random Forest classifier was used due to its interpretability and stability under varying data. To support the retraining decisions and reduce false alarms, statistical tests were used to check for changes in data distribution. Specifically, Jensen-Shannon divergence was applied to compare recent data windows and confirm whether actual drift had occurred. This helped reinforce the system's sensitivity to meaningful changes rather than noise.

Results showed that combining ADWIN with statistical testing led to better detection of performance drops and more effective recovery through retraining. The method offers a lightweight and efficient way to maintain model performance in changing environments. These findings suggest a promising direction for building adaptive, real-time systems that can respond to evolving threats in network security. Future research may extend this work by applying the method to additional datasets, exploring other drift detectors, and evaluating performance in live or real-time scenarios.

**Bio.** Jaycie Nguyen is a sophomore at Vanderbilt University majoring in Computer Science with a minor in Data Science. She is passionate about the intersection of machine learning and cybersecurity, with a specific interest in building adaptable models for real-time security applications. Jaycie is currently conducting undergraduate research in the VeriVITAL Lab under the guidance of Taylor T. Johnson, where her work focuses on detecting and addressing concept drift in network-based malware classification.

## 10 | Joshua Jenkelowitz | VUSE Summer Research Program

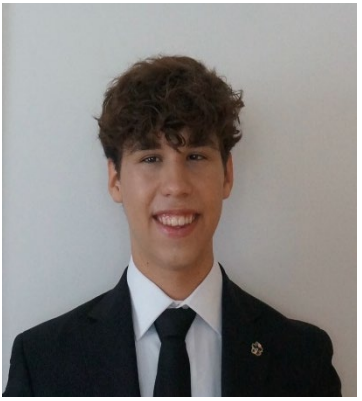
**Designing Diagnostic-Grade Primers for Singleplex PCR Assays**

**Joshua Jenkelowitz**[1a], Rick Haselton[1b]

*[1a]Author's Affiliation: Department of Biomedical Engineering, Vanderbilt University, Nashville, TN*

*[1b]Author's Affiliation: Principal Investigator, Department of Biomedical Engineering, Vanderbilt University, Nashville, TN*

The continuous evolution of pathogenic diseases requires adaptive diagnostic methods that are globally accessible. As pathogens evolve, PCR diagnostics must adapt through rapid design of new primers. We present a Python–based algorithm that integrates Primer3.py and BioPython with a composite scoring system to optimize four key primer metrics: melting temperature, GC% content, amplicon length, and structural stability. Upon the user input of a target sequence, the algorithm evaluates primers against user-defined constraints in a multi-step process. The tool calculates thermodynamic properties using the 1998 SantaLucia nearest-neighbor models, which exemplifies how DNA bases interact to predict melting temperature. To minimize structural interference, the algorithm applies ΔG thresholds to predict homo- and hetero-dimer formation, with GC% and amplicon-size constraints considered. Each metric is normalized and combined to rank primers by overall diagnostic suitability. Using three pathogenic targets (Cytomegalovirus, West Nile Virus, and Hepatitis C Virus), we benchmarked our primer selection against IDT PrimerQuest. Graphical output confirmed the location of our primers within the amplicon. Our primers achieved comparable $T_m$ (±0.5 °C) and GC% (±5 %) compared to other gold standard methods. This unified framework streamlines the rapid development of singleplex assays, offering a globally accessible solution for evolving PCR diagnostic requirements.



**Bio.** Joshua Jenkelowitz is a rising sophomore at Vanderbilt University majoring in Biomedical Engineering. From Fanwood, New Jersey, Joshua has been involved in healthcare since July 2021, working during the COVID-19 pandemic in acute care settings. After witnessing the rate of spread and behavior of the SARS-CoV-2 virus, he began to show an interest in infectious disease and clinical biology. Joshua's aspirations include working in immuno-engineering with a focus on human-pathogen interactions. In his free time, Joshua loves to spend time hiking and volunteering.

## 11 | Kyle Coutray | VUSE Summer Research Program

**NERV: A Comprehensive Framework for Rapid, Reproducible, and Hardware-Synchronized Neuroscience Experiment Design**

**Kyle Coutray**[1], Christos Constantinidis[2]
[1]*College of Engineering, College of Biomedical Sciences, University of Central Florida*
[2]*Department of Biomedical Engineering, Vanderbilt University*

The Neuro-Experimental Runtime for Vanderbilt (NERV) is a novel Unity-based software framework designed to streamline the creation, execution, and data logging of behavioral neuroscience experiments. Built entirely in C#, NERV encapsulates experiment logic within the Unity engine, offering a unified platform for experimental design and execution. A key innovation is its rapid, no-code prototyping capability, enabling users to generate fully functional experiments with minimal technical effort. NERV achieves this by automating traditionally programming-intensive steps, including scene and script generation, timing and state transitions, and seamless data acquisition and hardware synchronization. The framework provides a "low floor, high ceiling" approach, allowing non-programmers to create complex, interactive experiments while offering advanced users the flexibility to extend and modify underlying modules due to its modular, open-source design. NERV integrates millisecond-precision timing with robust data provenance through automatic code and data logging, and it easily interfaces with external hardware, significantly accelerating experiment development and enhancing reproducibility.

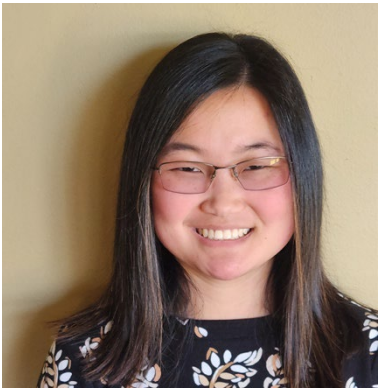
**Bio.** Kyle Coutray is a dual-degree scholar at the University of Central Florida, pursuing a B.S. in Computer Engineering and Biomedical Sciences on a Neuroscience track. As one of only two students in UCF's Medicine-Engineering Dual Degree (MEDD) program, he integrates circuit design, cognitive science, and immersive computing to address translational challenges in neuroscience and rehabilitation. At UCF's BRaIN Lab, he led the creation of a VR neurorehabilitation system that translates sensor-driven limb movements into avatar control. His earlier project, NeuroGaze, integrated EEG and eye-tracking into a hands-free VR interface, mentored by Dr. Joseph LaViola. Kyle is a recipient of the prestigious Astronaut Scholarship, Daniel D. Hammond Engineering Fellowship, Burnett Honors Rising Star Scholarship, College Skateboarding Educational Foundation Scholar of the Year Award, and Florida Bright Futures Academic Scholarship. He serves as a UCF Presidential Ambassador and previously served as President of the Biomedical Engineering Society, driving growth through interdisciplinary collaboration.

## 12 | Marissa Paul | VINSE NSF-REU

**Determining the Effect of Radiation-Induced Neutrophil Activation on Endothelial Monolayer Permeability**

**Marissa Paul**[1], Shannon Martello[2], Marjan Rafat, Ph.D.[2]
[1]*Department of Chemistry, Susquehanna University, Selinsgrove, PA*
[2]*Department of Chemical and Biomolecular Engineering, Vanderbilt University, Nashville, TN*

Triple negative breast cancer (TNBC), one of the most aggressive forms of breast cancer, lacks expression of common molecular targets resulting in limited treatment. Common treatment regimens include neoadjuvant chemo- and immunotherapy, surgery, and radiation therapy (RT). Despite RT typically reducing the likelihood of recurrence, approximately 20% of TNBC patients recur, and previous studies from our lab indicated that interactions between neutrophils and the vasculature play a significant role in this process. Because normal stromal tissue is exposed to radiation during treatment, we hypothesized that treatment results in a pro-tumor microenvironment that enables circulating tumor cells to be recruited to the irradiated site. Our objective was to study the effect of radiation and neutrophils on the integrity of an endothelial monolayer in a three-dimensional model. To study the permeability, endothelial cells (ECs) were cultured on inserts to form a monolayer before exposure to RT. A trans-endothelial neutrophil migration assay was then performed at six hours and two days post-RT to evaluate the integrity of the monolayer. FITC-dextran was used to analyze permeability, and immunocytochemistry was used to identify gaps between the cells by visualizing CD31, a protein highly expressed on the membranes of ECs. Permeability decreased following the addition of neutrophils. The morphology of the ECs also showed significant changes after the addition of neutrophils when visualizing CD31, indicating potential activation by the neutrophils. The three-dimensional model to study the interactions between neutrophils and the vasculature will continue to be optimized and compared to microfluidic devices that mimic mammary tissue in the future. By using three-dimensional models and incorporating shear stress to better replicate *in vivo* conditions *in vitro*, we aim to be able to study cellular interactions and test potential treatments more accurately without the use of animal models.



**Bio.** Marissa Paul is an undergraduate at Susquehanna University, pursuing a B.S. in Biochemistry with minors in Spanish and Psychology. She works under Dr. Swarna Basu on various biological uses of nanoparticles and polymers and is a co-author on a paper published by the lab. For her summer research at Vanderbilt, she is working in Dr. Marjan Rafat's lab under her graduate student mentor Shannon Martello to study the permeability of cell monolayers in a three-dimensional model Outside of research, she currently serves as co-president on the board for the program Supporting Minorities Rigorous Tracks in STEM (SMARTS) at her university which strives in providing opportunities, empowerment, and support to everyone at her school. After graduating from Susquehanna University, she plans to pursue a Ph.D. and work in a national lab or industry.

## 13 | John Delaney | Chemical Biology NSF-REU

**The kinetics of aggregation of insulin II B9-23 (R22E) peptide variant**

**John Delaney**[1,2], Cade Rohler[2], Lauren Buchanan[2]
[1]*Department of Chemistry, Lafayette College, Easton, PA 18042*
[2]*Department of Chemistry, Vanderbilt University, Nashville, TN 37235*

The hormone insulin plays an essential role in glucose homeostasis. Insulin B9-23 peptides, the shortest biologically functional fragments of insulin, are recognized as antigens by CD4+ T cells, which cause autoimmune destruction of insulin-producing $\beta$-cells resulting in type-1 diabetes. The effect of insulin B9-23 peptides on the $\beta$-cells is unclear, but they are understood to form amyloid fibrils. Insulin II is a mouse homologue of human insulin, and the R22E variant has been shown to have a higher affinity for CD4+ T cells. Many techniques are utilized to study the aggregation pathway of amyloids; however, two-dimensional infrared spectroscopy (2D IR) can be used to calculate transition dipole strength (TDS) measurements, which quantify the vibrational coupling between modes. Furthermore, 2D IR spectra uniquely show cross peaks, which elucidate interactions and the coordination between coupled vibrational modes, particularly the amide-I modes associated with the carbonyl stretch of peptides. For these reasons, 2D IR is a powerful method of observing peptide structures and more complex protein systems, such as repeating $\beta$-sheets. Using 2D IR and TDS measurements, we examined the kinetics of aggregation of insulin II B9-23 (R22E) variant into amyloid fibrils.

**Bio.** Jack is rising senior at Lafayette College in Easton, Pennsylvania studying a B.S. in biochemistry. He has worked in the lab of Dr. Justin Hines since January of 2023 working on and leading projects elucidating the interactions of prion diseases and chaperone proteins in *Saccharomyces cerevisiae*. Additionally, he is president of the McKelvy Scholars Program- Lafayette's honors program, president of Lafayette's American Chemical Society chapter, a supplemental instructor and teaching assistant for general chemistry courses and labs, a peer mentor for prospective chemistry undergraduate students, and an EXCEL and Bergh research fellow. Jack is currently conducting research in the Buchanan Lab at Vanderbilt University through the NSF's REU program, studying insulin peptide amyloid formation and kinetics using 2D IR spectroscopy.

## 14 | Durga Moorthy | VUSE Summer Research Program

**Objective Gaze Metrics to Evaluate Assistive Mixed Reality for Kidney Surgery**

**Durga Moorthy**[1], Jumanh Atoum[1], Jie Ying Wu[1]
[1]*Dept. Of Computer Science, Vanderbilt University*

Mixed reality (MR) guidance, a deeper integration of digital content into the physical environment, is increasingly used in image-guided surgery to improve precision and training. In endoscopic kidney surgery, quantifying surgeon attention via eye gaze may offer insights into expertise and help develop adaptive MR systems for performance feedback and skill acquisition.Surgeon eye gaze was tracked in real-time using the HoloLens 2 headset paired with a lab-developed Unity app. This study explores how experts and novices differ in visual behavior during ureteroscopies performed both unguided and under MR guided conditions, where guidance was delivered by projecting expert eye gaze to follow. To date, we have collected eye gaze data from six users across multiple tasks (scoping and ablating). We refined our data collection protocol, addressed key limitations from earlier trials, and selected robust gaze metrics that enable quantitative analysis of task difficulty and skill level. Initial machine learning analysis indicates that novices with AR guidance exhibit more "expert-like" gaze behaviors than novices without guidance. Preliminary patterns also suggest that experts display more sustained fixations over longer procedures compared to novices. However, a larger dataset is needed to reliably confirm these findings. This ongoing project aims to expand data collection to over 100 surgical cases within the next year. Future analyses will utilize advanced machine learning approaches, including convolutional neural networks (CNNs) and long short-term memory architectures, to capture both spatial and temporal patterns within gaze behavior. With a larger dataset and sophisticated analysis, we aim to develop accurate, scalable models of surgical attention to improve training and assessment.

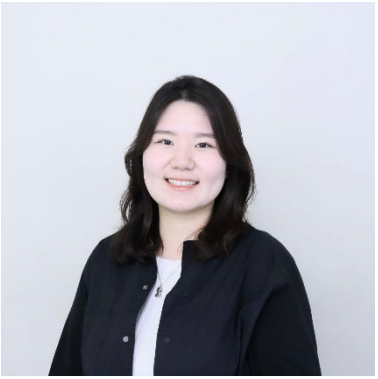
**Bio.** Durga Moorthy is a biomedical engineering undergraduate from Sunnyvale, California, and currently serves on the board of the Society of Women Engineers at Vanderbilt University. She joined the MAPLE (Machine Automation Perception and Learning) Lab as a freshman and is currently a Summer Fellow at the Vanderbilt Institute for Surgery and Engineering (VISE), conducting research under the mentorship of Dr. Jie Ying Wu. Her work centers on data analytics and clinical applications in surgical technology. Durga's research projects include analyzing eye gaze behavior during augmented reality–guided endoscopic kidney procedures, where she leverages machine learning techniques for data processing and analysis. Additionally, she contributes to multi-institutional efforts by processing endoscopic video data as part of a collaborative ARPA-H project. Driven by her interest in the intersection of technology and medicine, Durga aims to build a career in surgical engineering following graduation.

## 15 | Dawn Oh | VU Undergraduate Summer Research

**Engineering Multimeric Albumin Binding Proteins for Half-Life Extension of STING Agonists in Vivo**

**Dawn K. Oh**[1], Neil Chada[2, 3], John T. Wilson [1, 2]
[1] *Department of Chemical and Biomolecular Engineering, Vanderbilt University, TN, USA*
[2] *Department of Biomedical Engineering, Vanderbilt University, TN, USA*
[3] *Medical Scientist Training Program, Vanderbilt University School of Medicine, TN, USA*

There has been increased interest in leveraging the cGAS/STING pathway—an innate immune signaling cascade that elicits a pro-inflammatory response—to improve the efficacy of cancer immunotherapeutics against solid tumors. However, because the cGAS/STING pathway is expressed by all cells, systemic delivery of agonists can result in off-target toxicity. One way to overcome this challenge is by targeted drug delivery. Our lab has demonstrated that nanobodies targeting albumin (nAlb), used as carrier proteins conjugated to a STING agonist (diABZI), increase the half-life of STING agonists and localize more to tumors than to other organs. However, the relationships between nanobody affinity to albumin, serum half-life, and tumor targeting are not known. Therefore, this project aims to investigate how changes in albumin affinity affect serum circulation and tumor targeting. Multiple nAlb domains were recombinantly fused and expressed in *E. coli*, generating nanobody chains with 2 or 3 albumin-specific subunits. After characterization of nanobody conjugates using mass spectrometry and SDS-PAGE, AlphaFold and Biolayer Interferometry (BLI) confirmed structural integrity and quantified binding affinity. BLI exhibited an increasing trend in affinity, as indicated by decreasing KD values: double-domain nanobodies showed a 10-fold reduction compared to single-domain, and triple-domain nanobodies a 1000-fold reduction. As the results confirmed that increasing the number of nanobody domains enhanced their affinity to albumin, future research will focus on *in vivo* administration in mice to evaluate pharmacokinetics in serum and tumor targeting of different nanobody chains.



**Bio.** Dawn Oh is a rising third-year undergraduate student at Vanderbilt University from Iowa and South Korea, majoring in Chemical Engineering with minors in Engineering Management, Chemistry, and Materials Science. She joined the Wilson Immunoengineering lab in January 2025 and was selected for the VUSRP cohort that same year.

## 16 | Zeyu Zhao | VUSE Summer Research Program

**Implementation of Pre-trained Segment Anything Model for Two-Phase Flow Analysis**

**Zeyu Zhao**[1], Andrew Noonan[2], Amrutur Anilkumar[2]
[1]*Department of Physics, Mount Holyoke College, South Hadley, MA*
[2]*Department of Mechanical Engineering, Vanderbilt University, Nashville, TN*

In the present work, we evaluate the pre-trained Segment Anything Model (Version 2; SAM2) for automated bubble tracking for size and speed evaluation in aerated lubricant flow encountered in Internal Combustion Engines. The goal of the present study is to use bubbly flow images to identify parameter settings that yield robust segmentation across a wide range of lubricant flow conditions. Such work can be adapted for flow speed estimation and bubble measurement in challenging contexts with overlapping bubbles or nonuniform lighting.

Using our experimental image datasets with a wide range of fluid velocities and bubble sizes, a custom procedure was developed to generate the image masks required for bubble segmentation and measurement. We apply a Sobel operator to generate high-contrast edge maps and extract candidate bounding boxes and seed points for each sampled frame. Then, SAM2 is prompted using these candidate boxes at multiple scales (pad ratios), and the returned masks are filtered by their IOU score and stability. To determine the combination of parameters that maximize segmentation performance while minimizing computation time, we performed a full factorial sensitivity sweep over parameters used to generate candidate boxes, pad ratios, and stability and IOU thresholds. Segmentation quality was assessed against manually annotated ground-truth masks using pixel-level metrics (IOU, Dice/F1, precision and recall). Optimal performance was obtained with a Sobel kernel size of 7, edge gradient threshold of 0.32, a padding-ratio vector of [0.0, 0.4, 1.0, 1.3], and joint stability/IOU thresholds of 0.8-0.9, which together deliver a favorable balance between segmentation precision, recall, and processing speed (average per-frame runtime < 1min). This is an improvement over the base automatic mask generation processing time of ~5 minutes per image at the requisite prompt grid density. Overall the test conditions, this implementation achieved a mean pixel-F1 (Dice) of $0.80 \pm 0.02$, a mean IOU of $0.68 \pm 0.05$, mean precision of $0.96 \pm 0.04$, and mean recall of $0.68 \pm 0.03$. These results demonstrate that SAM2 base models, without any task-specific fine tuning, can be a reliable and efficient tool in segmenting individual bubbles in challenging contexts. The fast processing time achieved over automatic mask generation enables future work at high throughput levels suitable for real-time or large-scale experimental studies.

**Bio.** Zeyu Zhao is a student at Mount Holyoke College, majoring in physics and mathematics.

## 17 | Bryce Ware | VU Undergraduate Summer Research

**Implementation of the Laboratory Radiation Test Training Simulator**

**C. Bryce Ware**[1], Timothy Krentz[2], Brian D. Sierawski[1], Michael L. Alles[1], Andrew L. Sternberg[1]
[1]*Vanderbilt University – Institute for Space and Defense Electronics*
[2]*Vanderbilt University – Institute for Software Integrated Systems*

The Laboratory Radiation Test Training Simulator recreates the single event testing experience at a typical heavy ion accelerator facility: like a flight simulator for radiation testing. Due to the high cost of testing, limited facility availability, and low numbers of trained workforce, the project aims to provide a testbench for familiarizing researchers with the testing environment and to dry run their own equipment. To interface with simulator hardware in a way that better emulates the testing experience, custom software was written to connect existing cyclotron control software from Texas A&M with the hardware. This software consists of three main components: the original TAMU control GUI with a custom backend, a ZeroMQ server for handling threading, and a firmware module for sending the proper control signals to the hardware. Future work will consist of refining the system with installer scripts and assembly documentation for implementation by future customers.

**Bio.** Bryce Ware is a rising junior majoring in Electrical & Computer Engineering at Vanderbilt University. He is from Blue Ridge, GA in the Southern Appalachian Mountains. Bryce has been working at The Institute for Space and Defense Electronics furthering the Lab RaTTS project, performing maintenance on the Pelletron particle accelerator, and experiencing his first heavy ion test trip at the Texas A&M Cyclotron Institute. In addition, he is a member of the VINSE tech crew and the IEEE Nuclear and Plasma Sciences Society. Bryce is interested in device physics and circuit design for radiation hardened electronics in space applications; he hopes to continue his involvement in heavy ion testing and spend the upcoming semester researching high angle test methods.

## 18 | Olcaytu Hatipoglu | VIBES

**Life in Deep UV: Toward Multimodal Deep Ultraviolet Imaging for Rapid Biomedical Discovery**

**Olcaytu Hatipoglu[1,2,4]**, Miguel de Jesus[3,4], Anupam Kumar[5], Alec Walter[4], Anita Mahadevan-Jansen[3,4], and Bryan Millis[3,4]

1 Tulane University
2 VIBES Program (Vanderbilt Internship in Biophotonics for Emerging Scholars)
3 BioMIID Program (Biomedical Microscopy, Immersion, Innovation, and Discovery)
4 Vanderbilt Biophotonics Center, Vanderbilt University School of Engineering
5 The Wond'ry, Vanderbilt University School of Engineering

Traditional histological techniques are time-consuming, labor-intensive, and reliant on protocols that compromise tissue integrity. These pose significant challenges in diagnostics, as well as in surgical interventional settings where such processing and annotation are required before subsequent intervention can proceed. Microscopy with Ultraviolet Surface Excitation (MUSE) enables intrinsic optical sectioning by leveraging the shallow penetration depth of deep UV light to visualize tissue surfaces without the need for fixation, embedding, or sectioning. High-contrast images can be obtained with brief staining (or none at all), preserving sample integrity and dramatically reducing turnaround time. While the bulk of work in this area has focused on generating H&E-like imagery for the benefit of pathologists, this study focuses specifically on imaging *unstained* tissue samples to explore the full potential of label-free contrast under deep UV illumination to provide information on tissues of interest. By shifting the focus toward biomolecular autofluorescence, we aimed to leverage MUSE to reveal innate tissue contrast, obviating the need for any staining. By integrating simultaneous detection of multiple emission signatures, in combination with multi-wavelength excitation from multiple perspectives, our system captures structural and compositional insights often discarded when the sole goal is H&E mimicry. Our system further eliminates the need for deep learning pipelines or extensive computational analytics. With a relatively crude preparation protocol and real-time imaging capability, MUSE supports rapid feedback (<30 mins) from fresh or cryosectioned samples, capturing innate tissue contrast and topography. Ongoing developments, including multi-perspective imaging, wavelength tuning, and elastic scatter detection, among others, aim to expand MUSE into a multimodal platform for deeper tissue insight and broader biomedical research applications.

**Bio.** Olcaytu Hatipoglu is an undergraduate biomedical engineering student at Tulane University with a minor in electrical engineering. She currently conducts research as a 2025 VIBES (Vanderbilt Internship in Biophotonics for Emerging Scholars) Fellow at the Vanderbilt Biophotonics Center. Her work focuses on the development of multimodal ultraviolet imaging systems for label-free tissue analysis and rapid diagnostic applications. Hatipoglu's academic and research interests span biophotonics, tissue optics, and medical imaging technologies aimed at improving accessibility and clinical efficiency. In addition to her research, she serves as a STEM tutor for a wide range of engineering and pre-medical courses and competes as a Division I athlete on Tulane's varsity swimming team. Her honors include repeated selection to the Dean's Honor List, recognition as a TOM-University Fellow, and two American Athletic Conference gold medals and school records.

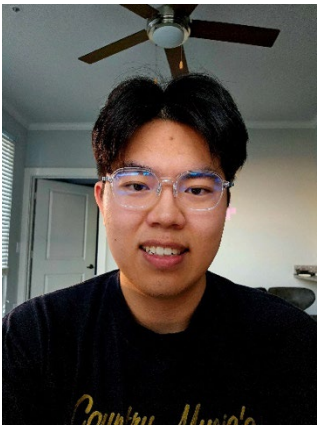
## 19 | Yilin Liu | VUSE Summer Research Program

**SmartSeg: A Non-Parametric Approach for Wearable Camera Video Segmentation**

**Yilin Liu**[1], Hanchen David Wang[2], Haowei Fu[2], Madison Lee Mason[3], Fanjie Li[4], Alyssa Wise[4], Daniel T. Levin[5], Gautam Biswas[2], Meiyi Ma[2]

[1]*Department of Electrical and Computer Engineering*
[2]*Department of Computer Science*
[3]*Department of Psychology*
[4]*Department of Teaching and Learning*
[5]*Department of Psychology and Human Development*

Wearable cameras provide an efficient and convenient way to record our lives, supporting real-time documentation and analysis across various domains. Recent research has explored diverse methods for temporal segmentation, which aim to transform unstructured video data into structured events. This transformation facilitates deeper video understanding, optimizes computational resources, and improves the accessibility and interpretability of video content for both machines and humans. However, unlike conventional videos, wearable camera recordings present unique challenges. These include highly unstable camera perspectives, diverse activities across various environments, and flexible duration. This paper introduces SmartSeg, a non-parametric approach for segmenting wearable camera videos without labeled data. By capturing the fundamental meanings of the video, SmartSeg aggregates the video through the Temporal Self-Similarity Metric encoder and groups sequences of frames into coherent events through clustering techniques. We evaluated SmartSeg on three diverse datasets. We conducted a real-world case study on nursing simulations, demonstrating SmartSeg's ability to effectively segment complex, noisy interactions with diverse activity transitions.



**Bio.** Yilin Liu is a master's candidate in Electrical and Computer Engineering at Vanderbilt University. His research spans explainable AI, deep learning, and computer vision, with recent work on temporal segmentation of nursing-simulation videos and knowledge distillation for activity recognition. He previously conducted undergraduate research at Rensselaer Polytechnic Institute on drone design and vehicle dynamics simulation and completed internships at CRSC Innovation Investment Company Ltd. Current projects include KD for video activity recognition, a clinical-skills segmentation model, and physics-informed graph neural networks for real-world applications. Liu plans to continue pursuing ML/AI research that bridges algorithmic transparency with real-world impact.

## 20 | Safa Mbarki | VINSE NSF-REU

**Calibration of an NO Sensor for Quantification of NO Production in an Engineered Model of Neurovascular Coupling**

**Safa Mbarki**[1], Johanna Pearson[2], Leon M. Bellan[3,4]

[1] *Department of Mechanical and Aerospace Engineering, Rutgers University, New Brunswick, NJ 08901*

[2] *Interdisciplinary Materials Sciences Program, Vanderbilt University, Nashville, TN, 37235*

[3] *Mechanical Engineering, Vanderbilt University, Nashville, TN 37235*

[4] *Biomedical Engineering, Vanderbilt University, Nashville, TN 37235*

Many neurological conditions, such as Alzheimer's disease and stroke, have been linked to impaired neurovascular coupling (NVC), resulting in insufficient local blood flow in metabolically active regions of the brain. NVC is the dynamic, multi-cellular signaling pathway by which neural activity modulates local cerebral blood flow to support areas of increased metabolic need. Due to ethical and practical limitations inherent to human and animal models, development of an iPSC-derived patient-specific model of NVC is crucial to advancing research for neurological disorders. Our model focuses on the well-established Glu-NMDAR1-nNOS-NO pathway at the parenchymal arteries. In this signaling pathway, glutamate produced by active neurons causes nNOS+ GABAergic neurons to produce nitric oxide (NO), a powerful vasodilator. As a first step to modeling this process, we have cultured iPSC-derived GABAergic neurons and demonstrated, qualitatively, their ability to produce NO upon glutamate exposure. To quantify NO production in this system, we now employ an amperometric sensor that can be calibrated to yield signals corresponding to known concentrations of NO. The sensor is calibrated using chemical production of NO, relying on the reaction between copper (II) chloride dihydrate and S-Nitroso-N-acetyl-D-penicillamine (SNAP, an NO donor molecule). The resulting calibration data is then used to convert sensor readings to NO concentrations. With this approach, we will be able to quantify NO release from GABAergic neurons, supporting our efforts to establish a model of NVC that can be used to study and develop treatments for NVC dysfunction.

**Bio.** Safa Mbarki is a rising junior at Rutgers University majoring in mechanical engineering. This summer, as a part of the VINSE REU program, she is conducting research at Vanderbilt University in Dr. Leon Bellan's Lab for Advanced Materials, under the mentorship of graduate student Jojo Pearson.

**Leveraging Albumin Hitchhiking for Carrier-free Cas9 Ribonucleoprotein delivery**

**Xuan Liu**[1], Larry D. Stokes[2], Craig Duvall[2]
[1] *Warwick Medical School, University of Warwick, Coventry, United Kingdom*
[2] *Engineering and Science Building, Vanderbilt University, Nashville, Tennessee, United States*

The need for a carrier-free delivery system of CRISPR/Cas9 for gene therapies stems from the drawbacks of current cargo forms, including immunogenicity and charged lipid cytotoxicity in viral vectors or lipid nanoparticles. We thus hypothesise carrier-free therapies can be developed leveraging an albumin hitchhiking mechanism to preferentially accumulate in inflamed tissue, allowing specific targeting of systemic diseases such as Duchenne's Muscular Dystrophy (DMD). As such, we aimed to engineer Cas9 constructs with the albumin binding domain (ABD), as either terminal or internal ABD constructs, modifying base triNLS Cas9 plasmids for increased nuclear import. Once validated with Next-Generation Sequencing, constructs were transformed into Rosetta2 (DE3) and induced with IPTG for protein isolation. Afterwards, the following purification steps were taken: IMAC, Heparin IEX and SEC, each validated with SDS-PAGE for purity. To investigate the editing effectiveness of the Cas9 constructs *in vitro*, the enzymatic activity was assessed using plasmid cleavage assays and an mTmG NIH3T3 reporter cell line. Engineered constructs were observed to remain enzymatically active after modification to varying degrees: internal ABD constructs demonstrated increased GFP activation in the reporter following Cas9 cleavage events compared to the HiFi control, whereas N terminal ABD constructs performed poorly in comparison with minimal fluorescence. These initial findings demonstrate promise as a carrier-free therapy mechanisms, particularly internal ABD constructs, but require further *in vivo* studies and verification.

**Bio.** Xuan Liu is an incoming 3rd year undergraduate student studying Integrated Natural Sciences at the University of Warwick. Having an interest in molecular biology and interdisciplinary science, she has a range of previous research experience: studying faithful cytokinesis in *S. pombe*, elucidating the role of surfactant protein C through the I73T mutation, and industrial antibody purification and conjugation at Abcam. She has also accumulated multidisciplinary experience through a series of 11 2-week research projects aimed at answering scientific questions revolving around the central topic: 'What is life?'. She was recipient of the Dean's Award for both Year 1 and Year 2 academic performance, scoring top of her cohort overall, as well as the Henry Pearson Gates Prize for A-level performance. To increase engagement of her peers with science, she also organizes talks and seminars as the Social Secretary in the Warwick Integrated Sciences society, having helped host guest speakers such as Paul Nurse and Richard Losick. She will be advancing in her 3rd year to a research project aimed at developing photostable red fluorescent proteins.

## 22 | Ella Montgomery | Chemical Biology NSF-REU

**Chiral Ion Mobility: Developing a Rapid Assay to Probe for Enantioselectivity using Ion Mobility-Mass Spectrometry**

**Ella R. Montgomery**[1,2], Benjamin K. Blakley[2], Jody C. May[2], John A. McLean[2]
[1]*Department of Chemistry, Wake Forest University, Winston-Salem, NC 27106*
[2]*Department of Chemistry and Institute of Chemical Biology, Vanderbilt University, Nashville, TN 37235*

Molecular chirality plays an important role in drug discovery. While one enantiomer can exhibit desirable therapeutic effects, its chiral counterpart can exhibit limited bioactivity or even detrimental effects. Thus, developing rapid analytical probes for chirality represents a significant challenge for the pharmaceutical industry. An emerging chiral separation method relies on ion mobility-mass spectrometry (IM-MS) combined with solution-phase complexation strategies, which can impart enantiospecific structural differences. Importantly, these structural differences can be directly resolved with structurally selective IM-MS instrumentation. In a previous approach, complexation to copper and an amino acid chiral reference ligand enabled direct resolution of racemic drug mixtures. However, this method displays limited throughput due to the extensive screening process required to determine whether a chiral drug is amenable to separation using a given complexation modality. This is particularly daunting given the sheer substrate scope of possible metals, chiral reference ligands, and chiral drugs. Here, we report a rapid assay for chiral IM separations that employs a 1:1 mixture of *D*- and *L*-amino acids to access both gas-phase chiral conformations for ternary copper complexes, thereby decreasing screening time by a factor of 3. We first present proof-of-concept for this assay, comparing results with data obtained using conventional techniques. Next, we present preliminary findings from a high-throughput screening for chiral IM separations using the assay. Future directions include incorporating a broader panel of chiral drugs for screening and implementing protocols to quantify enantiomeric excess in assayed samples.

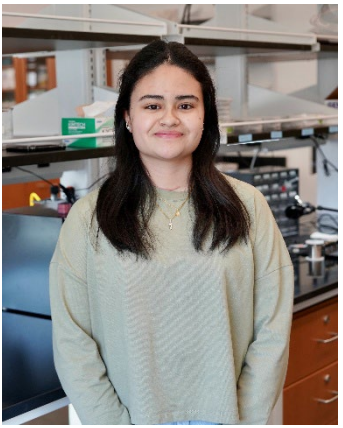
**Bio.** Ella Montgomery is an undergraduate researcher with research and laboratory experience in both analytical and organic chemistry. She is majoring in chemistry with a concentration in medicinal chemistry at Wake Forest University and is about to enter her 3rd year at the institution. Ella is most interested in researching pharmaceutical drugs and has worked on projects involving their synthesis as well as their characterization. She is pursuing graduate studies and aims to become a professional researcher, joining the effort to better understand the chemistry behind therapeutic drugs that are used by millions every single day.

## 23 | Micaela Gonzalez Mora | VINSE Tech Crew

**Electroplating Methods for Soft Lithography**

**Micaela Gonzalez Mora**[1, 2], Owen Meilander[3]
*[1]Department of Mechanical Engineering, Vanderbilt University[2]; Vanderbilt Institute of Nanoscale Science and Engineering, Vanderbilt University[3]; Vanderbilt University, Interdisciplinary Material Science*

This project explores methods of electroplating to develop more robust molds for soft lithography. Electroplating is a deposition technique that coats a metal object with a layer of another metal using electrolysis. It is widely used in research and industry, particularly in electrical and biological applications. There has been renewed interest in developing electroplating capabilities in conjunction with other VINSE cleanroom fabrication processes. Soft lithography traditionally relies on SU-8, a light-sensitive polymer commonly used to create molds. However, molds on silicon wafers made solely from SU-8 can peel off over time. The goal of this project is to introduce electroplating into the soft lithography process by making molds out of electroplated copper and nickel, so they can last longer while being used as molds for microfluidic devices. To begin the project, the equipment for electroplating was set up and tested. After several rounds of troubleshooting pneumatics and power sources, copper and nickel films were successfully deposited. In the initial copper samples, high concentrations of chlorine were detected, around 30%. The procedure was modified, and a new copper solution was made; the chlorine concentration decreased by 15%. This was correlated with a more uniform observed coverage of deposited copper. Additionally, by creating a detailed procedure of operations for electroplating, cleanroom users and staff will be able to effectively apply this technique once again. Reestablishing electroplating practices will enhance the quality and longevity of soft lithography molds and encourage broader applications in both biological and engineering research, such as general semiconductor electrodes and brain electrodes.



**Bio.** Micaela Mora is a rising junior in the school of engineering, majoring in mechanical engineering with a minor in digital fabrication. She was part of the VINSE Tech Crew program during the summer of 2025, and her research focuses on developing an electroplating technique for Soft Lithography. Besides the Tech Crew, she is part of the board in the Society of Hispanic Engineers at Vanderbilt, and she is also a member of Theta Tau Professional Engineering Fraternity.

## 24 | Mehal Kanhere | VUSE Summer Research Program

**A Massively Parallel Universal Transmit Array for High Field MRI**

**Mehal Kanhere**[1], Adam Anderson[2]
[1]*Mechanical Engineering, University of Texas at Austin*
[2]*Biomedical Engineering, Vanderbilt University and Vanderbilt University Institute of Imaging Science (VUIIS)*

Magnetic Resonance Imaging (MRI) is a non-invasive imaging technique that uses magnetic fields and radiofrequency (RF) pulses to produce detailed images of the interior of the body. High-field MRI, such as 7 Tesla (7T), uses a stronger magnetic field than 1.5T or 3T, and can produce higher resolution imaging. However, there are challenges in producing uniform RF magnetic fields at these high frequencies (because the wavelength of the field is smaller than the dimensions of the body). Coils in these machines can produce inhomogeneity and inefficient transmission, including in head imaging. The aim of this project is to build an 8x8 array transmit coil for 7T brain MRI. The array consists of 64 cuboid-shaped elements arranged in eight rows in an octagonal prism. Each cuboid contains three orthogonally oriented RF loop coils, forming a tri-planar shape for independent control of orthogonal dipole fields and similar transmission in all directions. This geometry was chosen to minimize inductive coupling and unwanted resonance between the loops. Each looped wire connects to an attached circuit board, which holds two variable capacitors and one fixed capacitor. The variable capacitors allow for adjustment of the coil's frequency to match the Larmor frequency of hydrogen at 7T (~300 MHz). The circuit board then connects to the two conductors of a coaxial cable. Current flows from the inner conductor through the capacitors and the loop to generate the oscillating magnetic field. The coil design builds on prior array simulation studies and designs and allows for flexible control over field shaping and potential parallel transmission strategies. By improving RF field homogeneity and transmission, improvements in high-field MRI can be made.

**Bio.** Mehal Kanhere is a Mechanical Engineering undergraduate at The University of Texas at Austin with a concentration in biomedical applications. Her work spans computational medical imaging research and the design of innovative medical devices. As founder and team lead of multiple medical technology organizations on campus, she actively drives interdisciplinary collaboration at the intersection of engineering and healthcare.

## 25 | Aarij Atiq | VU Undergraduate Summer Research

**Investigating Adversarial Robustness of Spiking Neural Networks**

**Aarij Atiq**[1] , Taylor T. Johnson[1,2]
[1]Department of Electrical and Computer Engineering, Vanderbilt University, *Nashville, TN, USA*
[2]Institute for Software Integrated Systems, Vanderbilt University, *Nashville, TN, USA*

Spiking neural networks (SNN) are have gained widespread recent attention as an energy-efficient, event-driven class of brain-inspired computing models capable of low-powered inference. The sparse, temporally encoded spike representations of SNNs promise significant reductions in power consumption compared to conventional Artificial Neural Networks (ANN), making them ideal for edge applications in the IoT, embedded systems, and robotics. Previous studies have shown that SNNs offer higher robustness to adversarial inputs than ANNs but there is little research on the formal verification and analysis of SNNs response to adversarial inputs.

In this study, we systematically investigate the impact of adversarial inputs on the functional dynamics, focus patterns, and classification accuracy of first-time-to-spike SNN architectures. Leveraging established attack methods such as Fast Gradient Sign Method (FGSM) and Projected Gradient Descent (PGD), we quantify how minimal perturbations shift key temporal metrics, including first-spike latency distributions and inter-spike intervals, and reduce overall model robustness. To visualize internal feature attributions, we adapt gradient-based class activation maps (Grad-CAMs) to spiking frameworks, uncovering how adversarial perturbations alter both spatial and temporal focus distributions across network layers. Additionally, we employ Satisfiability Modulo Theory (SMT) based solvers to perform formal verification on spike-latency models, encoding timing constraints and synaptic thresholds to derive provable guarantees of correctness under bounded perturbations. By combining empirical robustness evaluation with formal verification techniques, this work aims to establish comprehensive methodologies for enhancing the safety, reliability, and deployment-readiness of SNNs in resource-constrained, safety-critical applications.

**Bio.** Aarij Atiq is a rising senior at Vanderbilt University majoring in Electrical and Computer Engineering with a combined Masters in Cyber-Physical Systems Engineering. His research interests lie in cyber-physical systems, machine learning, and formal verification. Aarij spent his summer at the VeriVITAL Lab at the Vanderbilt Institute of Software Integrated Systems where his research focused on developing formal verification methods for neuromorphic computing

## 26 | Sophi Theriault | Chemical Biology NSF-REU

**Identification and Functional Analysis of Enzymes Involved in K-26 Biosynthesis in *Astrosporangium hypotensionis***

**Sophi Theriault**[1,2], William Payne2, Brian O. Bachman2
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In this study, we investigated the biosynthetic machinery of the phosphonopeptide K-26, a nanomolar angiotensin converting enzyme inhibitor produced by *Astrosporangium hypotensionis*. K-26 consists of *N*-acetylated isoleucine, tyrosine, and the non-proteinogenic amino acid (*R*)-1-amino-2-(4-hydroxyphenyl)ethylphosphonic acid (AHEP). Bioinformatic analysis of the producing organism's genome revealed a gene cluster of interest containing three genes of interest. Gene *GBKDDPCE_01640* encodes a protein with both AAT_like/HisC and SAM-binding domains, suggesting a role in AHEP formation from tyrosine. Translated genes *GBKDDPCE_01637* and *GBKDDPCE_01638* share 41% and 47% homology with the genes responsible for encoding AglL and AglC, tRNA synthetase dependent GNAT-family enzymes known for catalyzing amide bond formation in phosphonopeptide biosynthesis. We hypothesize that this region is responsible for K-26 biosynthesis, with '01640 employing a novel mechanism of phosphonate bond formation with AHEP biosynthesis. The three enzymes, along with corresponding tRNA synthetases for Ile and Tyr, were heterologously expressed and purified from *E. coli* BL21(DE3). Biochemical assays monitored by UPLC-HRMS were used to assess '01640's activity in AHEP synthesis. Results are expected to show catalytic function for '01640. The tyrosine and isoleucine addition is expected to be mediated by '01637 and '01638; however, further studies will determine their substrate specificity and functional redundancy.

**Bio.** Sophi Theriault is a biochemistry student at California State University San Marcos, where she conducts undergraduate research, investigating the synthesis of mimetic enzyme iron-sulfur complexes. She has presented her work at the 2025 Emerging Researcher's National Conference and the CSUSM CSTEM R&D Day. As a founding member of the Chemistry Biochemistry Academic Association (CBAA) and a lead tutor for the STEM Success Center, she is committed to peer mentorship and scientific community building. Sophi's academic dedication and leadership reflect her passion for advancing inclusive and collaborative science. She plans to pursue a Ph.D. in chemistry with a focus on natural products, aiming to contribute to a research community that broadens scientific understanding through a faculty role at a research-focused institution.

## 27 | Anna Ruth Madera| VINSE NSF-REU

**Generation of iPSC-Derived BMECs through Developmentally Relevant WNT Signaling Using CRISPR Activation**

**Anna Ruth Madera**[1], Hannah Brien[2], Daniel Chavarria[3], Jonathan M. Brunger[2], Ethan S. Lippmann[3]
[1]*Biomedical Engineering Department, Mercer University*
[2]*Biomedical Engineering Department, Vanderbilt University*
[3]*Chemical and Biomolecular Engineering Department, Vanderbilt University*

The blood-brain barrier (BBB) is a highly selective, semipermeable membrane that lines the blood vessels in the brain. One of the most critical cell types involved in BBB function are brain microvascular endothelial cells (BMECs), which form the lining of the brain's vasculature. BMECs modulate BBB function due to their tight junctions, transport channels, and cell adhesion molecules. Current *in vitro* models of the BBB utilize primary BMECs, which tend to dedifferentiate and lose their barrier function. To overcome this limitation we have developed a differentiation protocol for deriving synthetic BMECs (SynBMECs) from a human induced pluripotent stem cell (iPSC) source using developmentally relevant Wnt signaling. We expect SynBMECs to express the key features of human BMECs, including tight junction proteins (Occludin and Claudin), transport channels (P-glycoprotein (PGP) and glucose transporter 1 (GLUT1)), and cell adhesion molecules (VE-cadherin and CD31). Using CRISPR Activation, we have genetically engineered an iPSC line that can express Wnt in the presence of doxycycline (Dox), which we confirmed with quantitative polymerase chain reaction. To confirm the cell identity of this new SynBMEC line, we used immunofluorescence (IF) imaging and performed image analysis. Images suggest that SynBMECs treated with Dox showed increased expression of tight junction proteins Occludin and Claudin and transporter PGP in a more uniform monolayer compared to untreated SynBMECs. Additionally, image analysis of percent positive area indicates increased levels of GLUT1, CD31, and VE-cadherin and decreased levels of smooth muscle in Dox-treated SynBMECs compared to the untreated condition. Future studies will characterize the cell line using trans endothelial electrical resistance (TEER) to assess barrier function and RNA sequencing to directly compare gene expression profiles between synBMECs and primary BMECs.

**Bio.** Anna Ruth Madera is a rising senior at Mercer University majoring in Biomedical Engineering, with minors in Physics and Chemistry. Her passion for research began her freshman year when she co-founded a hydroponics research group in the Environmental and Civil Engineering Department at Mercer with Xzavier Longacre under Dr. Sarah Bauer. Since then, Anna Ruth has continued to build her research experience. Last summer, she studied hydrogel microsphere formation in the Young Lab, under the mentorship of Rachel Moen in Vanderbilt's Chemical Engineering Department, and now she has ompleted a summer with the VINSE REU in the Lippmann Lab, where she was co-mentored by Dr. Daniel Chavarria and Hannah Brien. There, she gained hands-on experience with CRISPR-activation and cell engineering techniques. After graduating in the spring, Anna Ruth plans to pursue a career in the biotechnology industry, where she hopes to combine her love for research and technology to make devices that can change people's lives.

## 28 | Riona Siffermann & Jacob Stoebner | VUSE-SRP

**A low-cost microscope for three-dimensional embryo imaging**

**Jacob Stoebner**[1], **Riona Siffermann**[1], Yunqin Zhao[1], Audrey K. Bowden[1]
[1]*Vanderbilt Biophotonics Center and Department of Biomedical Engineering*

In vitro fertilization (IVF) is a common treatment method for infertility. Embryo quality is a key factor in IVF success and is assessed by an embryologist who analyzes images taken of the embryos as part of the embryo selection process. We designed a low-cost microscope for three-dimensional imaging of embryos to aid in the embryo selection process for IVF. The inverted microscope uses a 40x objective lens paired with a tube lens and is encased in custom-designed, 3D-printed housing. A Raspberry Pi coordinates a programmable LED panel with a low-cost, high-quality camera to take images. We demonstrated that our microscope produces high quality bright field and dark field images that reveal the morphology of a mouse embryo. Embryos are traditionally imaged with a bright field microscope, and the addition of simultaneous dark field imaging produces images with higher contrast without the need to stain samples. We were also able to view the embryo at multiple cross-sectional depths using a digital refocusing algorithm. Our system is small enough that multiple units can be placed in an incubator and operate simultaneously, and the automation of the image capturing process frees embryologists from needing to remove the embryo from the incubator every time it must be imaged. This microscope design leads to more efficient embryo grading while also providing morphological and morphokinetic factors that can be analyzed by embryologists, which could lead to improved IVF outcomes.

**Bio.** Jacob Stoebner is a rising senior at Vanderbilt University studying Biomedical Engineering and Classics. He is in his second year working in the Bowden Biomedical Optics Laboratory. He recently completed a semester studying abroad in Rome, Italy, at the Intercollegiate Center for Classical Studies. He also serves as the Editor-in-Chief for *The Vanderbilt Hustler*, the university's student-run newspaper.

**Bio.** Riona Siffermann is a rising junior at Vanderbilt University studying Biomedical Engineering and Spanish. She conducts research in the Bowden Biomedical Optics Laboratory through the VUSE Summer Research Program. Her research involves low-cost medical devices and reproductive health. At Vanderbilt, she teaches science to middle school students through Vanderbilt Student Volunteers for Science, participates in the Tikkun Olam Makers Makeathon, and recently served as the Secretary of the Engineering Council.

## 29 | Davis Bone | VUSE Summer Research Program

**Computational Imaging Markers for Therapeutic Response**

**Davis Bone**[1,2,5], Dr. Jon Heiselman[1,2,3,4]
*[1] Vanderbilt University, Department of Biomedical Engineering, Nashville, Tennessee, United States*
*[2] Vanderbilt University, Vanderbilt Institute for Surgery and Engineering, Nashville, Tennessee, United States*
*[3] Vanderbilt University Medical Center, Nashville, Tennessee, United States*
*[4] Memorial Sloan-Kettering Cancer Center, Hepatopancreatobiliary Service, Department of Surgery, New York, New York, United States*
*[5] College of Arts and Sciences, Johnson and Wales University, Providence, Rhode Island, USA*

Pancreatic ductal adenocarcinoma (PDAC) is often characterized by poorly defined lesions and low imaging contrast, which hinder accurate evaluation of therapeutic response. Current non-invasive clinical markers, including the Response Evaluation Criteria in Solid Tumors (RECIST) and blood-based biomarkers CA19-9 and CEA, are widely considered insufficient descriptors of PDAC treatment response. Longitudinal image registration between pre- and post-treatment scans offers a potential approach for generating imaging biomarkers that more reliably quantify therapeutic response across time, independent of imaging contrast and modality. In this study, thirty-four patients who prospectively received neoadjuvant chemotherapy followed by surgical resection were retrospectively analyzed. A greedy image registration method was used to quantify longitudinal strain changes in both tumor and non-tumor pancreatic tissue across the treatment interval. Registration errors within the pancreas were evaluated, and registration-derived response metrics were correlated with overall survival (OS) and recurrence-free survival (RFS) over a five-year follow-up period. Manual tumor segmentation, RECIST evaluations, and pathological analysis of resected specimens were used as clinical comparators. Correlations between each variable and pathologic response were assessed using Spearman's rank correlation coefficient.

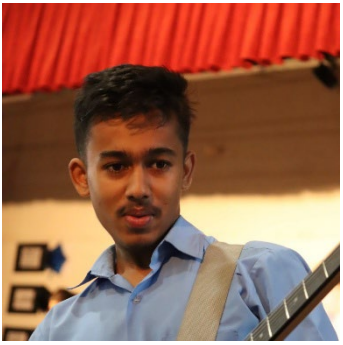
**Bio.** Davis Bone (he/him) is a rising fourth-year undergraduate at Johnson & Wales University in Providence, RI, majoring in General Biology and Biomedical Engineering. Born in St. Louis, MO and raised in San Diego, CA, Davis grew up with a love for sports—playing soccer, golf, baseball, and ice hockey. He currently trains and competes with his university's Men's Ice Hockey team and enjoys surfing and golfing in his free time. In summer 2022, his interests in the gut microbiome and human health led him to join the Gilbert Lab at UC San Diego, where he has since contributed to research on the gut-brain axis, coral reefs, the International Space Station, kombucha, and human skin—spanning bench work, data analysis, and protocol development. Most recently, his growing focus on biomedical engineering and medicine brought him to the Mallard Lab under Dr. Jon Heiselman as part of the VISE Summer Fellows and VUSE Summer Research programs.

**Reinforcement Learning in partially-observable stochastic systems**

**Vision Raj Panta**[1]
[1]*Fisk University*

The project explores how reinforcement learning (RL) agents can efficiently learn to navigate risky and uncertain partially observable environments—such as those found in robotics, autonomous navigation, and financial trading—using the FrozenLake game environment as a testbed. The goal was to investigate how different reward structures, state representations, and neural architectures impact learning performance and decision-making under risk. We began with standard Double Deep Q-Network agents using one-hot state encodings, which were effective on fixed maps but failed to generalize. To improve spatial awareness and generalization, we developed CNN-based agents and explored reward shaping techniques, improving success rates from 65% to over 98% in deterministic environments. When introducing stochasticity (slippery dynamics), agent performance dropped sharply. We addressed this by adding non-sparse rewards for better learning and incorporating a safety shield mechanism during runtime action selection. This shield filtered out actions likely to result in slipping into holes, raising win rates from 36% to 75% without retraining. This demonstrated how neurosymbolic architectures significantly outperform classical RL architectures in both performance and computational demand. Finally, we transitioned to a partially observable setting and developed a Transformer-based DDQN agent to retain memory across time steps. This model achieved a 98% win rate despite limited state visibility, outperforming traditional RNN and LSTM models by 37%. These findings demonstrate that risk-aware reward structures and memory-based architectures can significantly improve RL performance in uncertain environments.

**Bio.** Vision Panta is a rising sophomore majoring in Computer Science at Fisk University. His academic and research interests span AI/ML, full-stack development, and quantitative finance. Over the past year, he has contributed to data research through a collaboration with the Atlanta University Center Consortium. He is currently an AI research intern at Vanderbilt's Institute for Software Integrated Systems.



Looking forward, he aims to pursue roles that combine research and engineering with practical application, with the goal of solving complex, real-world problems through technical rigor.

## 31 | Genevieve Biberdorf | Chemical Biology NSF-REU

**Genome mining of pyrrole-containing antibacterial natural products**

**Genevieve Biberdorf**[1,2], Christine Ancajas[2], Allison Walker[2]
[1]*Department of Chemistry, Eastern Illinois University, Charleston, IL 61920*
[2]*Department of Chemistry, Vanderbilt University, Nashville, TN 37235*

The increase in the number of antimicrobial-resistant pathogens has led to an increasing need for the development of new antibiotics. Natural products (i.e., substances found in nature that have not been appreciably modified by humans) have long served as a foundation for many approved and widely used antibiotics.

Traditionally done by high-throughput screening, evaluating these products for drug development has become cost-intensive and laborious. As a result, the discovery of useful natural products dwindled. In response to this issue, computational methods have shown great success in identifying active metabolites produced by natural products. These methods include antiSMASH for predicting biosynthetic gene clusters (BGCs), machine learning for predicting activity, and Global Natural Product Social Molecular Networking (GNPS) for identifying BGC analogs. The goal of this study is to combine these computational methods with a stable isotope labeling approach to identify pyrrole-containing natural products. Pyrroles are frequently observed in compounds with antimicrobial and antifungal activity, and this work aims to explore whether their presence is predictive of biological activity. Using these computational methods combined with labeling of various actinomycetes with [1-$^{13}$C] acetate, [methyl-$^{13}$C] methionine, [1-$^{13}$C] propionate, and [1-$^{15}$N] glutamate, mass spectrometry identified biosynthetic gene clusters featuring these ideal pyrrole containing compounds. The results demonstrate the ability of a combined computational approach with stable isotope labeling to correctly identify functional modalities needed for the development of necessary antibiotics.

**Bio.** Genevieve Biberdorf is a rising senior at Eastern Illinois University. Graduating with a B.S. in Biochemistry, her research focuses on utilizing computational methods to model the pyrolysis of Teflon monomers to decrease environmental hazards. Outside of research, she serves as the vice president of the local American Chemical Society chapter, is a proud member of the women's swim team, and serves as a representative on the Student Athlete Advisory Committee. She plans to attend graduate school in 2026 and pursue a PhD in chemistry to ultimately become a research scientist in pharmaceuticals.

## 32 | Samuel Tamayo-Sarver | VISE Fellowship Program

**Umbilical Vein Pulsed-Wave Doppler Analysis for Preeclampsia Prediction: Arduino Phantom Flow Simulation & Envelope Extraction**

**Samuel Tamayo-Sarver**[1], Jingyi Zhu[1], Brett Byram[1]
[1]*Department of Biomedical Engineering, Vanderbilt University, Nashville, TN*

Preeclampsia, often leading to leaky capillaries, vasoconstriction, clotting abnormalities, along with many other maternal endothelial dysfunctions is terrible pregnancy condition affecting many pregnant mothers. According to millionhearts.hhs.gov, about 1 in 25 pregnancies in the US suffer from preeclampsia, and according to OBGYN, it accounts for about 16% of maternal deaths in high-income countries. Logarithmic ratio of maternal to fetal spectral peak (LRSP) is a promising biomarker to predict preeclampsia. LRSP is defined as log10(maternal power/fetal power) and compares the relative fetal and maternal power of umbilical vein flow.

We need to analyze the parameters for different power spectrum estimation methods and figure out which method is the best in this task. We hope to explore the various umbilical vein profiles to determine if LRSP can be a consistent and precise biomarker for preeclampsia across different profiles. With a limited amount of clinical data, we aim to create a phantom project that could simulate the blood flow in the umbilical vein for more analysis.

An Arduino-controlled stepper-motor-pump array drives cornstarch-water, blood-mimicking fluid, through silicone tubing. Firmware modulates the pumps' duty ratio for different amplitudes of maternal and fetal components, exploring different umbilical vein profiles. A Siemens SC-2000 ultrasound machine with 9L-04 transducer acquired the Pulsed-Wave (PW) doppler waveform signal, and we used different methods to extract the velocity envelope. After, we estimated the power spectrum of the envelope via Discrete Fourier transform, Capon's, and Welch's method. Using the power spectrum we identified the maternal and fetal peaks for the LRSP computation.

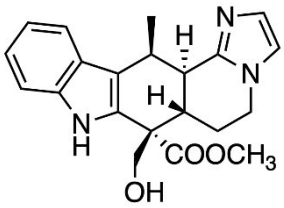
We developed a simple, reproducible bench-top system that can generate PW Doppler waveform data for subsequent short DICOM analysis. This framework enables rapid, low-cost validation of prediction algorithms around PW Doppler for pregnancies.

**Bio.** Samuel Tamayo-Sarver is a rising Junior pursuing a BME/ECE double major with a minor in Digital Fabrication at Vanderbilt University. He prides himself on his ability to create and is most proud of his international patent for a telehealth device for palpation --- PCT/US2024/015883. If he's not working in Stevenson 5 on a Biomedical/Electrical related project, you'll find him out building devices for Sayvant or Vituity, hiking, at the gym, playing soccer, or hobby DIYing with 3D printing or woodworking. He is currently doing research at Vanderbilt as a part of the Vanderbilt Institute for Surgery and Engineering Program.

## 33 | Gavin Higgins | Chemical Biology NSF-REU

**Progress Towards the Total Synthesis of Alscholarine A**

**Gavin Higgins**[1,2], Chase Hamelink[1], Steven Townsend[1]
[1]*Department of Chemistry, Vanderbilt University, Nashville, TN 37235*
[2]*Department of Chemistry, Davidson College, Davidson, NC 28036*




Alscholarine A (**1**)

Natural products, with their complex structures and diverse bioactivity, are a valuable source of pharmaceutical compounds and biological probes. Additionally, their synthesis serves as a platform for developing novel synthetic methodologies. Recently, we took interest in the monoterpene indole alkaloid Alscholarine A, which incorporates a fused pentacyclic ring system with two distinct nitrogen heterocycles and four contiguous stereocenters. Preliminary bioactivity studies have shown that Alscholarine A possesses vasorelaxant and anti-inflammatory effects. Herein, we report progress toward a 13-step total synthesis of Alscholarine A, highlighted by key transformations including a hydrogen bond catalyzed double Michael addition and an iridium photocatalyzed ring closure to form Alscholarine A's fused piperidine ring system. A densely functionalized key intermediate, the double Michael addition product, has been synthesized, and current efforts are focused on achieving the photocatalytic ring closure. Synthesis of this molecule would add potential therapeutic options, and importantly, establish a framework for creating and modifying similar highly functionalized compounds, enabling the exploration of new bioactive molecules.

**Bio.** Gavin Higgins is a rising sophomore at Davidson College in North Carolina, where he studies chemistry and art. He is currently conducting research in Dr. Steven Townsend's laboratory, working with Ph.D. student Chase Hamelink on the total synthesis of Alscholarine A. This fall, he will begin research in a glycosciences laboratory at Davidson, working on glycomimetic structures under the mentorship of Dr. Nicole Snyder. Originally from Nashville, Gavin graduated cum laude from the University School of Nashville. His academic interests include organic synthesis, glycoscience, and exploring the intersection of chemistry and art.

## 34 | Xuelin Yang | VUSE Summer Research Program

**Exploration of Tridentate Ligands on Halogen-terminated Hybrid MXenes**

**Xuelin Yang**[1,2], Vikash Khokhar[2], De-en Jiang[2,3]
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[2]*Interdisciplinary Material Science, Vanderbilt University, Nashville, TN, 37203*
[3] *Department of Chemical and Biomolecular Engineering, Vanderbilt University, Nashville, TN, 37203*

Two-dimensional (2D) transition metal carbides and nitrides (MXenes) have rising research potential in chemical modifiability, which provides promising insights towards applied studies of interfaces. Previous studies have shown that MXenes exerted decent tunability in incorporating deprotonated organic amine ligands onto halogen-terminated surfaces by replacing halogens, to form hybrid MXenes (h-MXenes). Progress has been reported in functionalizing h-MXenes with amido- and imido- groups in the form of mono- and bidentate amine ligands. On the track of exploring polydentate terminated MXenes with increasing steric hindrance, we hereby examined the stability and reactivity of tridentate ligands, starting with simple triamine organic structures. We selected triamines with three-carbon chain, triangular structure carbons, and hexagon structure carbons as backbone, and further simulated the optimized structures combining triamines with termination-free ($Ti_3C_2$) and hybrid MXenes ($Ti_3C_2Br_2$). We calculated the binding energies and reaction energies at different coverages using density functional theory (DFT). Further, *Ab initio* Molecular Dynamics (AIMD) simulation was used for investigating the stability and dynamics at experimental temperatures. The resulting tridentate liganded h-MXenes have exhibited strong bond strength in the equivalent level compared with bidentate ligand systems, which indicate the orientation of tridentate ligands has been placed properly without compromising the strength of bonds. The reaction energies in formation of tridentate ligands have also been explored and confirmed the need of strong deprotonating reagents. This study presents an encouraging preliminary finding of the possible polydentate ligands on hybrid MXenes, which can be strategically leveraged to inhibit undesired aggregation, enhance surface accessibility, and stabilize active sites.

**Bio.** Xuelin Yang is a rising senior at Haverford College majoring in Chemistry and Mathematics at Bryn Mawr College. This summer, she was a research intern in Vanderbilt University's School of Engineering (VUSE) program. She conducted *ab initio* molecular dynamics (AIMD) simulations with VASP to investigate the tridentate ligand binding on hybrid MXene surfaces. Outside the lab, Xuelin plays as cellist in the BiCo (Haverford & Brynmawr) school orchestra and loves relaxing on a swing when the weather is nice.

## 35 | Zoie Dodson | VINSE NSF-REU

**Photosystem I – Polymer Composite Films for Improved Wiring of Photosystem I**

**Zoie Dodson**[1], Praise Eromosele[2], and G. Kane Jennings*[2]
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[2]*Department of Chemical and Biomolecular Engineering, Vanderbilt University, Nashville, Tennessee 37235, USA*

In nature, the Photosystem I (PSI) protein complex converts solar energy to chemical energy with nearly perfect quantum efficiency. Researchers have taken advantage of this phenomenon in the development of biohybrid photovoltaic devices for energy conversion. In previous work, PSI has been successfully immobilized onto gold electrodes in monolayers; however, a major limitation of these devices is the improper wiring between PSI and the electrode that results in poor electron transfer. Our objective is to integrate the growth of conductive polymers, polyaniline (PANI) and poly p-anisidine (PPA), with a PSI monolayer immobilized on a gold electrode to improve the wiring of these devices. To grow these polymers onto electrodes, we use cyclic voltammetry (CV) to electropolymerize them from dilute monomer solutions. CVs show growing peaks that are indicative of increasing current with polymer deposition. Ellipsometry shows increasing film thickness when the polymer is deposited onto a gold electrode with or without a submonolayer of PSI, thereby confirming the growth of conductive polymers on the surface. FTIR confirms the presence of both PSI and polymer on the surface of our films, reporting signals for the amide functional groups of PSI and benzenoid and quinoid functional groups of PANI and PPA. Finally, photochronoamperometry experiments with our composite films show increasing photocurrent generation, suggesting that electron transfer to the protein has improved in the presence of the polymer. In summary, we are able to control the growth of conductive polymers to synthesize PSI-polymer composite films. These polymers improve the wiring of PSI to the electrode, increasing the photocurrent generation of these biohybrid photovoltaic devices.

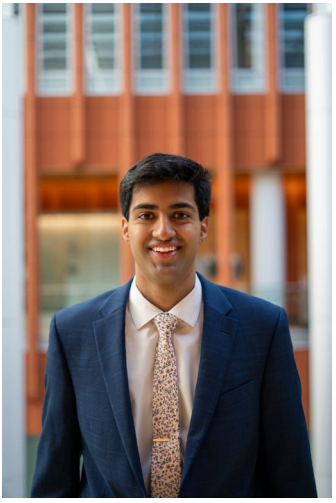
**Bio.** Zoie Dodson is a rising senior at Lycoming College studying Chemistry with a minor in Mathematics. This summer, she worked in the Jennings laboratory investigating conductive polymers to improve the wiring of biohybrid photovoltaic devices. In the past, Zoie performed synthetic organic chemistry research in the McDonald and Bendorf laboratories at Lycoming College. In the coming academic year, she will be carrying out an honors project titled, The Intramolecular Nucleophilic Ring Opening and Closure of Quaternized N,N-Acetals. At Lycoming College, Zoie is the president of the Gamma Sigma Epsilon Honor Society for Chemistry and Biochemistry, student vice president of the Phi Kappa Phi Honor Society, and secretary of Kappa Mu Epsilon Honor Society for Mathematics. Zoie is also involved in the Scholars program at Lycoming College and is the Class of 2026 representative on the Scholars Council. She has served as a general and organic chemistry tutor and as an organic chemistry teaching assistant. Zoie has achieved the following awards throughout her time at Lycoming College: Ada Remley Memorial Scholarship Award (April 2025), Haberberger Fellowship Award (April 2025), The Analytical Chemistry Award (April 2025), The Physical Chemistry Award (April 2025), Second Place in Organic Chemistry – Intercollegiate Student Chemists Convention (March 2025), Phi Kappa Phi Pioneer Award (July 2024), Organic Chemistry Award (April 2024), Fundamentals of Physics Award (April 2024), Rose Pfaff Scholarship (April 2024), Phi Kappa Phi Study Abroad Grant (April 2024), M.B. Rich Endowed Prize (April 2023).

## 36 | Milind Pulugura | VUSE Summer Research Program

**An improved synthesis of InflammaProbe-2 for targeted visualization of NLRP3 inflammasomes**

**Milind Pulugura**[1], MD Imam Uddin[1,2]
[1]*Department of Ophthalmology and Visual Sciences, Vanderbilt University Medical Center, Nashville, TN.*
[2]*Department of Biomedical Engineering, Vanderbilt University, Nashville, TN.*

Age-related macular degeneration (AMD) is one of the leading causes of vision loss in the elderly population. There are two major types of AMD: dry-AMD and wet-AMD. While dry-AMD is more common, wet-AMD is responsible for over 90% of AMD-related cases of blindness. Wet-AMD is driven by choroidal neovascularization (CNV), the abnormal growth of blood vessels from the choroid into the subretinal space. Vascular endothelial growth factors (VEGF) play a key role in promoting CNV, and the NLRP3 inflammasome is believed to regulate VEGF signaling, especially in the context of inflammation-driven angiogenesis. Given NLRP3's potential as a biomarker, various optical imaging techniques can be employed to detect its activity and monitor AMD progression. Early detection is critical, as it can help prevent vision loss in affected individuals. Ongoing research in Dr. Uddin's Lab focuses on understanding the pathogenesis of AMD. The goal of my research is to optimize the synthesis of InflammaProb-2, a chemical probe designed to detect NLRP3 activity. This probe is synthesized by conjugating a derivative of an NLRP3 inhibitor, MCC950, to a fluorescent dye, OregonGreen, through a multi-step process. Structural integrity and purity were confirmed at each stage using HRMS, $^{1}$H-NMR, and $^{13}$C-NMR. In my summer research project with the help of Dr. Uddin, I optimized the reaction to increase the yield of the synthesis, developed a new method for the deprotection of a tert-butyloxycarbonyl (Boc) protecting group using trifluoroacetic acid, and scaled the synthesis from milligram to gram quantities, indicating the method's viability for larger-scale production.



**Bio.** Milind Pulugura is a rising senior at the University of Michigan, where he is studying chemistry, biology, and business. He is originally from Philadelphia. During his time in Michigan, he worked in a microbiology and computational chemistry lab, where he studied the movement of flagella and the structure of carbonic anhydrase. Likewise, he is passionate about the intersection of technology and healthcare, leading him to MedLaunch, an organization that develops assistive technology for people with physical disabilities around Ann Arbor. His efforts have launched adaptive soccer at his university.

## 37 | Mario Lindero Barrera | VUSE Summer Research Program

**Design and Fabrication of Mechanisms to Automate Operation of Microfluidic Radiosynthesis Devices**

**Mario Lindero Barrera**[1], Mark Mc Veigh[2], Leon M. Bellan[3, 4]
[1]*Department of Mechanical Engineering, Vanderbilt University, Nashville, TN, 37235*
[2]*Interdisciplinary Materials Science Program, Vanderbilt University, Nashville, TN, 37235*
[3]*Mechanical Engineering, Vanderbilt University, Nashville, TN 37235*
[4]*Biomedical Engineering, Vanderbilt University, Nashville, TN 37235*

Positron emission tomography (PET) is a tool that allows clinicians to track biological processes using radiotracers. A radiotracer is a radionuclide-labeled biomolecule that can be injected into a patient and tracked by detecting its decay with a PET scanner. Currently, 95% of all PET scans use a single radiotracer (fluorodeoxyglucose [FDG]), but specialized radiotracers can provide more accurate diagnosis in many cases. Unfortunately, these more specific radiotracers are prohibitively expensive to synthesize at a single-dose scale. We aim to leverage microfluidic concepts to create a dose-on-demand benchtop synthesis platform, RAPID (Radiopharmaceuticals As Precision Imaging Diagnostics), that can be employed in the clinic. To enable automated use of microfluidic chips, several components were developed for this platform. These components were designed in Fusion360, sliced in Bambu Studio or Chitubox, and printed using either aqua-grey 8K resin or PLA. An Arduino Uno was used to test the motors and movement of the components before incorporating them into the ESP32-controlled platform. To automate fluid flow, custom syringe pumps that handle a variety of syringe sizes and flowrates were designed, built, and incorporated. Additionally, we developed an automated chip insertion system that transports the microfluidic chip from an external platform and precisely places it into its final operating position where a fluidic interface is engaged, and synthesis can begin. These innovations bring RAPID closer to a fully automated system capable of enabling precision nuclear medicine diagnostic and treatment approaches via dose-on-demand production of a variety of specialized radiotracers.

**Bio.** Mario Lindero Barrera is a rising Sophomore at Vanderbilt University studying mechanical engineering. Mario is a part of the VUSE Summer Research program and is in Dr. Leon Bellan's Lab for Advanced Materials. This Summer, Mario worked with Mark Mc Veigh, a rising 4th year PhD student, to conduct his research.

**On/Off Temperature Control on Custom-designed Integrated Circuits**

**Isaiah Brew**[1], Bharat Bhuva[1], Yoni Xiong[1]
*1Department of Electrical and Computer Engineering*

Precise temperature control is necessary during radiation testing because temperature fluctuations affect the underlying fundamental mechanisms. The temperature of the device-under-test needs to be maintained within 1 degree Celsius of any target temperature between 30 and 100 degrees Celsius. The researcher used a thermistor, to acquire data, an arduino microcontroller, to process the data and control the system, a 12V heater, to heat the custom-designed Integrated Circuit (IC), and a relay, to electrically turn on or off the heater. The resultant system is able to control the heat within 1 degree Celsius of the target point while accounting for hysteresis delay through software thresholds. Using python code, the device automatically logs the time and temperature data. Additionally, the device and experimental conditions are tailored to working with custom-designed printed circuit boards. The researcher ensured effective temperature stability through temperature measurements at 10 second intervals for 5 minutes for temperatures 30, 40, 50, 60, etc. Altogether, the On/Off Temperature control device is simple, cost-effective, and portable while maintaining temperature within 1 degree Celsius on printed circuit boards during Radiation Testing.

**Bio.** Isaiah Brew is studying Electrical Engineering at the University of Illinois at Chicago with an expected graduation date in May 2026. He has researched AI-controlled Unmanned Aerial Vehicle Landing at the Advanced Air Mobility REU at the University of Tennessee, Knoxville. His interests include embedded systems, autonomous control, and electronics for harsh environments. Isaiah aims to contribute to future aerospace and radiation effects technologies through innovative circuit design and intelligent control systems.

**Improving QC for Scanned Oblique Light Sheet Microscopy**

**Ishaan K. Singh**[1,3], Han Dong[3], Kanchana Devanathan[3], Miguel[3], Bryan Millis[3]
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Light sheet microscopy is now a well-established class of microscopy techniques for a range of applications, from high-speed sub-cellular imaging to large volume fixed tissues. Conventional light sheet methods utilize multiple objectives, and have little flexibility for samples due to the prohibitively small space in which the sample must be mounted. “Single objective” light sheet designs such as the scanned oblique plane illumination (SOPi) microscope address this problem with the use of only one objective for oblique excitation and epi-direction detection. This alleviates many of the problems light sheet conventionally poses, but the technique is still not available as a commercialized platform and involves a relatively sophisticated optical setup. As a result, the bioimaging community is forced to leverage open hardware builds by scientists from a range of disciplines, without robust and well-established quality control methodology. Here, to help enable widespread adoption of SOPi, we discuss our recent efforts to establish methods that reveal signatures of misalignment characteristic to a remote-refocused “single objective” light sheet platform. First, we introduce a novel method based on principal component analysis (PCA) to flexibly identify the light sheet angle (and thus skew) prior to image processing. Subsequently, we discuss the key analytics of 3-dimensional point spread functions (PSFs) that can be extracted to reveal misalignments in the system. By extracting those analytics in aligned and strategically misaligned configurations, we then can perform PCA to find the combinations of analytics that best indicate misalignment in the system. This project contributes to a suite of analytics being built to help researchers access critical optical platforms long before commercialization and thus accelerate the discovery process. It is our hope that this work will help researchers building SOPi microscopes ensure that their microscope performs as well as it can, and provide clear guidance as to what changes need to be made if it does not.

**Bio.** Ishaan Singh is a rising junior at Purdue University, double majoring in honors physics and biochemistry with minors in electrical engineering and math. He works with two professors at Purdue – with Dr. Jing Liu of the physics department, his work currently focuses on integrating widefield fluorescent lifetime imaging with spatial super-resolution microscopy. With Dr. Chi Zhang of the chemistry department, his work focuses on instrumentation and software for nonlinear microscopy, as well as optical control of subcellular processes. He is a recipient of the Lilly Scholars at Purdue scholarship, a 2025 Astronaut Scholarship Foundation awardee, a 2025 campus nominee from Purdue for the Goldwater scholarship, and a recipient of the Purdue Office of Undergraduate Research scholarship. In his free time, he likes to compose music for orchestra, play bloons tower defense 5, and watch poorly written comedies on Netflix.

**Polymer-Driven Activation of Engineered Cells to Direct Cancer Immunotherapy**

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[2]*Interdisciplinary Materials Science, Vanderbilt University, TN, USA*

According to the National Cancer Institute, over 2 million new cases of cancer and nearly 700,000 deaths are predicted to occur in 2025 in the US alone. Immunotherapy harnesses the body's natural immune response and is currently at the forefront of modern cancer treatments. However, its application is currently limited by the types of cancer it can effectively treat with significantly heterogeneous treatment outcomes. Many engineered cellular therapies utilize receptors that rely on extracellular cues for activation, such as target proteins on the surface of cancerous cells. It is often challenging to find a unique marker of tumors, leading to off target and potentially harmful side effects. To combat this, synthetic targets such as fluorescein, a small fluorescent marker, can be incorporated into polymers to improve efficacy and response. To find the optimal polymer that enhances the functionality of engineered cells, different sizes and valency were synthesized via reversable addition fragmentation chain transfer (RAFT) polymerization. Engineered cells were then treated with polymers ranging from 25 kDa to 100 kDa and with three different ratios of monomers. Cell activation was measured by fluorescent protein production, and it was found that the 100 kDa polymers drove the strongest response in cells, with monomer ratio having little impact. Additionally, the length of the polymer chain had positive correlation with activation. Moving forward, attention can be directed toward testing additional monomer classes and polymer structures.

**Bio.** Jieon Ki (Jenna) is a rising 3rd year ChBE student with a focus on materials science. She is from Atlanta, GA but has spent a large part of her life moving around the United States. She found interest in immunoengineering after the global pandemic in 2020, joining the Wilson Lab in October of 2024. Her lab work began protein engineering, involving production and purification of nanobodies in E. coli. This summer, it shifted to synthetic material synthesis and learning techniques such as RAFT polymerization and mammalian cell culture. Notable awards include her acceptance to VUSRP and the upcoming Houston Energy Trek cohort.

**Thermal Non-Equilibrium in Metals between Electrons and Phonons using a Two Temperature Model and Molecular Dynamics**

**Auris Vega**[1], Greg Walker[2], Brad Baer[3]
[1]*Vanderbilt University, School of Engineering*
[2]*Vanderbilt University, Department of Mechanical Engineering*
[3]*Vanderbilt University, Interdisciplinary Materials Science*

This project models how varying thermal conductivity and electron-ion coupling affect non-equilibrium thermal transport in a homogeneous metal where electrons and phonons contribute equally. Volumetric heating is also applied to drive the system out of equilibrium and to identify specific points where the electron and phonon subsystems diverse in temperature response. The simulations were conducted using Molecular Dynamics (MD) within LAMMPS, a material modeling simulation, specifically utilizing the Two Temperature Model (TTM) module. While standard MD captures atomic motion and phonon behavior, it does not account for electric thermal contributions. The TTM was implemented in conjunction with MD to simulate electron-phonon interactions and enable a more complete representation of thermal transport processes under non-equilibrium conditions.

The results show that increasing the electron-ion coupling causes faster thermalization between subsystems, while variations in thermal conductivity impact how quickly energy spreads throughout the material. The onset and duration of non-equilibrium states depend on the magnitude of volumetric heating and these two material parameters. These trends align with physical expectations and offer insight into heat transport behavior in systems subjected to rapid energy deposition. To extend the practical application of this modeling, the data is used to support the development of a non-dimensional equation. This simplified form enables estimation of non-equilibrium behavior in similar systems without requiring detailed atomistic simulations. Overall, this study provides a deeper understanding of electron-phonon transport and introduces a modeling approach that is applied to high-energy applications.

**Bio.** Auris Vega is a rising sophomore at Vanderbilt University majoring in Mechanical Engineering. She is a member of the Clark Scholars Program within the School of Engineering. Through this summer project, this has deepened Auris's interest in energy systems and thermal transport. Looking ahead, Auris hopes to continue developing her skills for computational modeling and further explore the role of simulation in advancing energy-efficient technologies.

**Porous Silicon-based Smartphone Biosensor for Point of Care Diagnostics**

**Eden X. Teo**[1], Zachary Martin[1], Sharon Weiss[1]
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Traditional optical biosensing methods require the use of spectrometers for optical readout, introducing a costly component that is typically not available outside a laboratory environment. However, the prevalence of digital imaging devices in the form of smartphones introduces an opportunity to develop optical biosensors that utilize smartphone imaging instead of spectrometers, thereby enabling rapid, point of care (POC) diagnostic tools that maintain the high sensitivity of optical biosensors while being broadly accessible. Here, we report on a porous silicon (PSi) optical biosensor that utilizes a smartphone for optical readout of color changes that occur when molecules infiltrate the PSi sensors. Three specific advances to this biosensor platform are discussed: (1) the incorporation of red (R), green (G), and blue (B) bandpass filters to convert broadband white light from the smartphone flashlight to RGB light that enables more sensitive detection of PSi color changes, (2) design and fabrication of a smartphone case to hold the RGB filters and PSi sensor within a controlled lighting environment, and (3) demonstration of good agreement between the measured change in RGB pixel values of the smartphone camera and the change in the optical spectrum measured by a spectrometer when ethanol is exposed to the PSi sensor. This work establishes the feasibility of developing a highly sensitive PSi smartphone-based biosensor for POC diagnostics that eliminates the need for specialized benchtop laboratory equipment and provides a quantitative sensing result as opposed to the binary diagnostic results typically given by current commercially available rapid POC tests.

**Bio.** Eden Teo is a rising junior and Crescere Aude Scholar at Vanderbilt University studying Electrical & Computer Engineering. She maintains a concentration in the field of photonics and nanomaterials, and holds minors in nanoscience & nanotechnology, digital fabrication and art history. Prior to joining the Weiss Photonics Lab at Vanderbilt, Eden conducted research at the University of Waterloo Microfluidics Lab in a joint project with the Harvard Medical School. Eden hopes to continue research and pursue graduate school aligning with her interests in photonics and nanotechnology.

## 43 | Cole Patterson | VINSE Tech Crew

**Oxide Demonstrations in Atomic Layer Deposition**

**Cole Patterson**[1,2], Ben Schmidt[2], Owen Meilander[3]
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*[2]Vanderbilt Institute of Nanoscale Science and Engineering, Vanderbilt University*
*[3]Interdisciplinary Materials Science, Vanderbilt University*

The Picosun R200 Advanced Plasma-Enhanced Atomic Layer Deposition (PE-ALD) system, often used in microchip fabrication for highly pure, controlled, and conformal material deposition, presents an exciting opportunity for nanofabrication in the Vanderbilt Institute of Nanoscale Science and Engineering (VINSE) Cleanroom. This research compares film uniformity, roughness, and thickness control between the until-recently non-functional ALD system and similar deposition methods such as $Al_2O_3$ sputter deposition (AJA ATC-2200) and $SiO_2$ plasma-enhanced chemical vapor deposition (Trion Orion II). For each comparison piece, roughly 50 nm of oxide was deposited on a 3-inch silicon wafer. A map of deposition thickness and surface roughness was then constructed using spectroscopic ellipsometry and atomic force microscopy, alongside chemical composition analysis using SEM-EDS. Surface roughness, refractive index, and deposition rate of ALD trimethylaluminum-sourced $Al_2O_3$ were also investigated as functions of substrate temperature, film thickness, and oxygen source to better understand the effects of ALD process parameters. For greater user accessibility, an ALD standard operating procedure and checklist were compiled. All data were consolidated into an online log with an adaptive thickness calculator available to trained users, enabling the creation of two viable high-κ metal-oxide-semiconductor (MOS) capacitors. Using p-type silicon substrates, sputtered aluminum contacts, and 100 and 5 nm each of ALD $Al_2O_3$ as gate oxides, the devices demonstrated uniform capacitances of 6.9e-5 and 0.76e-5 F / $cm^2$, with no shorting within the tested voltage range. As a final exercise, multiple 20 nm layers of ALD $TiO_2$ and PECVD $SiO_2$ were deposited on 1.8 µm-wide silicon pillars and imaged using STEM-EDS, visually demonstrating the consistency and conformality at which atomic layer deposition excels.

**Bio.** Cole Patterson is a sophomore in the Vanderbilt College of Arts and Science majoring in Physics and Philosophy. He joined the VINSE Tech Crew in the summer of 2025, where he studies atomic layer deposition. He is a member of the Society of Physics Students. He is a passionate reader and writer, having won the Phi Beta Kappa First-year Writing Award for an essay on Romantic poetry. A part-time Classicist, Cole enjoys the study of all things Roman, particularly numismatic.

## 44 | Bree Steinfeldt | Chemical Biology NSF-REU

**Developing an Electrochemical Metabolite Sensor for Fetal Membrane-On-A-Chip Applications**

**Bree Steinfeldt**[1,2], Sammi Calvez[2], David Cliffel[2]
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[2]*Department of Chemistry, Vanderbilt University, Nashville, TN 37235*

This project focused on the development of enzyme-based electrochemical sensors to monitor metabolite changes for a fetal membrane-on-a-chip (FMOC) to study interactions between maternal and fetal cells. By comparing signals from within the cell chamber and downstream, we aim to determine any significant difference between the two and use our findings for application to FMOC. Two different designs of electrodes from Pine Industries were silver-plated and functionalized with lactate oxidase and tested using lactose dilutions in RPMI 1640 media. Lactate oxidase was selected as the enzyme of interest because its activity indicates oxidative stress. VIIBRE microvalves and pumps were used to control the flow of the lactose dilutions while the CHI 1030 and 1440 potentiostats recorded electrochemical responses to generate a calibration curve. A successful calibration curve has not yet been achieved. Current troubleshooting efforts involve testing fresh lactose, adjusting electrode cleaning methods, and purchasing new lactate oxidase. Our goal is to determine the optimal lactate oxidase concentration in RPMI media and achieve a reproducible, linear range for metabolite detection. Although a stable calibration curve has yet to be established, current troubleshooting efforts are guiding improvements in sensor reliability. Optimizing enzyme concentration and refining experimental conditions will be key steps toward enabling consistent metabolite detection for application in fetal membrane-on-a-chip systems.

**Bio.** Bree is a rising senior at Ouachita Baptist University in Arkadelphia, Arkansas where she is a double major in Chemistry and Biology. She is the current president of her ACS student chapter and focuses on outreach in rural schools. Bree has completed research with Dr. Sara Hubbard at Ouachita in analytical chemistry. Her research focused on analyzing the amount of Bisphenol-A in women's athletic wear using fluorescent spectroscopy. She has presented her research at regional and national ACS meetings as well as state-wide conferences. She has won ACS Southwestern Regional Meeting Second Place Oral Presentation Award and Arkansas INBRE First Place Oral Presentation Chemistry Award. Bree is also a supplemental instructor for Organic Chemistry I & II and tutors other subjects. Bree plans to pursue a graduate degree in chemistry, with the long-term goal of entering academia and establishing her own research laboratory.

## 45 | Sebastian Martinez | VINSE NSF-REU

**Paper Based Microfluidic Channels for Porous Silicon Biosensors**

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[4]*Department of Chemistry, Vanderbilt University, Nashville, TN, USA*
[5]*Department of Biomedical Engineering, Vanderbilt University, Nashville, TN, USA*
[6]*Department of Electrical and Computer Engineering, Vanderbilt University, Nashville, TN, USA*

Developing low cost, highly sensitive, and accessible biosensing platforms is critical for widespread diagnostic applications. Porous silicon (PSi) is a promising material for these platforms due to its high surface area for detecting molecules, chemical and biological compatibility, and ease of fabrication. Integrating PSi membranes with paper substrates offers a pathway to creating portable, affordable diagnostic systems. However, controlling the incubation time of test solutions in PSi-on-paper sensors remains a significant challenge, limiting detection sensitivity. This project aims to create high resolution paper-based microfluidic channels that regulate flow rates and control incubation times for molecules captured in PSi-on-paper biosensors, improving their performance and reproducibility for rapid diagnostics.

We determined the most effective fabrication method for creating paper-based microchannels utilizes 3D-printed molds to rapidly prototype PDMS stamps. Microchannel stamps with various thicknesses and channel widths were inked with 100% concentration PDMS ink and tested for their ability to direct solution flow on paper substrates. Whatman filter paper and nitrocellulose paper were investigated to evaluate the effects of pore size on flow rates and incubation time.

Our results showed that 2 mm high 3D-printed molds produced durable, reproducible PDMS stamps for effective microchannel patterning. Experiments applying colored water to the paper-based microchannels demonstrated that wider channels enabled faster fluid transport and nitrocellulose paper, with smaller pores, provided more controlled flow. Preliminary integration of PSi membranes with these microchannels confirmed that narrower channels in nitrocellulose paper increased incubation times in PSi. Future work will optimize channel resolution and dimensions to achieve the desired incubation time for highest detection sensitivity of biomolecules of interest. These findings demonstrate the feasibility of integrating PSi membranes with PDMS-patterned paper microfluidics to create accessible biosensing platforms.

**Bio.** Sebastian Martinez is a rising fifth-year senior at The Ohio State University, where he is pursuing a Biomedical Engineering degree. With research experience in the intersection of photonics and biomedical application, Sebastian has developed an interest and passion for these fields. Previously, Sebastian interned in Dr. Thomas Bifano's Lab at Boston University's Photonics Center, where he developed high throughput screening systems and designed optical systems using waveplates and polarizers for computational polarimetric imaging. He also conducted research in the Swindle-Reilly Lab for Biomimetic Polymeric Biomaterials at Ohio State, designing ocular drug delivery systems and developing hydrogels for wet AMS treatment.

## 46 | Hunter Qin | VU Undergraduate Summer Research

**ConST transforms deep clustering into a scalable, transparent, and biologically informed framework**

**Hunter Qin**[1], Maizie Zhou[2]
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[2]*Department of Biomedical Engineering, Vanderbilt University*

Spatial Transcriptomics (ST) enables high-resolution mapping of gene expression within intact tissue and is widely clustered for cell-type inference, yet existing methods often rely on complex models, lack transparency, and underutilize spatial context. We present Contrastive Spatial Transcriptomics (ConST), a fast, scalable, and accurate framework that integrates a variational autoencoder with an optimal transport (OT) loss and contrastive learning guided by biological priors. ConST embeds expression profiles and spatial coordinates in a shared latent space by minimizing OT divergence to preserve tissue structure, while a contrastive loss aligns cells sharing marker gene signatures and separates dissimilar profiles, yielding scalable, noise-robust, and interpretable representations.

ConST improves clustering coherence and biological relevance over state-of-the-art tools across multiple ST datasets, such as human dorsolateral prefrontal cortex, mouse hypothalamus, and mouse spinal cord. Gradient saliency analyses of the contrastive module highlight marker genes driving each cluster. Moreover, ConST extends seamlessly to single-cell RNA-seq by incorporating read-count weighted priors, demonstrating its versatility across modalities. By unifying OT-based alignment with marker-informed contrastive learning, ConST transforms deep clustering into a transparent, biologically grounded framework, facilitating downstream discovery and validation.

**Bio.** Hunter Qin is a fourth-year BS/MS student at Vanderbilt University studying Computer Science and Mathematics. His research explores the mathematical foundations of geometric deep learning, optimal transport, and representation learning, with applications to modern transformers and biomedical discovery. At the Maizie (Xin) Zhou Computational Biology Lab, he applies geometric deep learning and optimal-transport–assisted representation learning to spatial transcriptomics and single-cell RNA-seq data. Concurrently, in the Machine Intelligence & Neural Technology (MINT) Lab under Dr. Soheil Kolouri, he investigates the theory of low-rank adaptation (LoRA) and model compression in large-scale transformer networks.

## 47 | Alejandro Benitez Galeano | VUSE Summer Research Prog.

**Non-Destructive Spectroscopic Screening of GaN Wafers for Low-Resistance Contact Viability via Machine Learning**

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[2]*Interdisciplinary Material Science, Vanderbilt University*

Gallium nitride (GaN) is a wide-bandgap semiconductor with exceptional potential for high-frequency and high-power electronics. However, GaN's surface complexity and high cost pose significant challenges in device fabrication. These difficulties are especially pronounced at the metal–semiconductor interface, where poor contact formation can reduce yield, increase resistance, or degrade device performance. Traditional evaluation methods, such as the circular transmission line method (CTLM), involve full fabrication of test structures, making it impractical to assess wafer quality at scale. This project explores a non-destructive wafer screening approach that leverages machine learning models trained on pre-metallization spectroscopic data to rapidly identify regions suitable for forming low-resistance ohmic contacts.

The core approach involves collecting surface-sensitive spectroscopic data from GaN samples before any metallization or device processing, using techniques such as Raman, FTIR, and photoluminescence (PL). These measurements provide information about the overall material and surface quality, including indicators of defects or non-uniformities across the wafer. The data will be processed to extract descriptive features that may correlate with electrical performance. The goal is to train a machine learning model to classify wafer regions as either suitable or unsuitable for device fabrication, using criteria derived from post-fabrication CTLM measurements. This framework aims to prioritize high-yield fabrication zones and reduce wasted processing on regions unlikely to support reliable, low-resistance contacts.

Initial spectroscopic characterization has been completed, and ongoing analysis is focused on identifying surface-level indicators that may inform device performance. As the methodology evolves, the project aims to refine both the data processing workflow and the classification framework. While still in early stages, this study establishes a foundation for a non-destructive, cost-effective screening strategy that could improve fabrication efficiency and reliability in GaN-based technologies.

**Bio.** Alejandro Benitez is an undergraduate student in Electrical and Computer Engineering at Vanderbilt University, currently conducting research on GaN-based semiconductor devices through the VINSE Summer Research Program. Originally from Asunción, Paraguay, his work focuses on developing non-destructive, data-driven methods for evaluating contact resistance in GaN using spectroscopy and machine learning. He has previously contributed to radiation testing of analog-to-digital converters with the Institute for Space and Defense Electronics and has led technical projects in embedded systems, analog electronics, and robotics. Outside the lab, Alejandro serves as a Head Resident, mentoring a team of resident advisors and supporting a residential community of over 800 students. He is also a FIDE Master in chess and a national medalist in Physics, Informatics, and Mathematics. Alejandro plans

to pursue a Ph.D. in Electrical Engineering and is passionate about advancing semiconductor technology and expanding access to STEM education.

## 48 | Chase Pyrah | Chemical Biology NSF-REU

**Progress Towards the Total Synthesis of Cochinmicin I**

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Cochinmicin I is a non-ribosomal cyclic depsipeptide with potent endothelin receptor antagonist (ERA) activity. It features two dihydroxyphenylglycine (Dpg) residues and a pyrrole-2-carboxylic acid moiety, assembled into a macrocycle through both amide and ester linkages. We have demonstrated the use of Umpolung Amide Synthesis (UmAS) to construct aryl glycinamides such as *feglymycin*—a linear aryl glycine-rich tridecapeptide—without the use of high molecular weight coupling reagents. However, aryl glycine esters remain challenging to access due to their tendency to epimerize and susceptibility to hydrolysis. Here, we employed modern Yamaguchi and Mitsunobu esterification techniques to explore the formation of aryl glycine esters. Furthermore, we investigated anhydrous UmAS conditions to preserve the ester linkage during amide bond formation. Together, these efforts are aimed at advancing an efficient and stereocontrolled total synthesis of cochinmicin I.

**Bio.** Chase Pyrah is an undergraduate chemistry student at Utah State University, he anticipates his B.S. Chemistry degree in spring 2026. There, he conducts research under Dr. Lisa Berreau, focusing on the synthesis and mechanistic studies of light-triggered carbon monoxide releasing molecules. He is currently conducting summer research at Vanderbilt University in the Johnston laboratory through the NSF REU program.

**Using 2D/3D Registration Loss to Optimize Landmark Detection Model**

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Automated landmark detection offers an efficient approach for medical professionals to analyze fluoroscopic images. While current detection methods for pelvic fluoroscopy demonstrate promising accuracy, most rely on a fixed Antero-Posterior view of the pelvic bone. However, during intraoperative imaging, patient orientation often deviates from this standard view due to unknown rotations and translations of the pelvis. To address this limitation, we propose a novel framework that incorporates 2D/3D landmark registration into the training of a U-Net landmark prediction model. By registering predicted 2D landmarks with known 3D annotations, we estimate the 3D camera pose. Because small deviations in 2D predictions can lead to significant pose errors, we use the camera pose discrepancy as a supervision signal. Synthetic fluoroscopic images are generated from Computed Tomography data using Digitally Reconstructed Radiographs, providing ground truth 2D landmarks and camera poses. The predicted landmarks are used to estimate pose via a differentiable optimization pipeline, and the pixel distance between the estimated and ground truth poses is backpropagated to fine-tune the baseline U-Net model. We analyze the performance difference by comparing landmark detection accuracy between the baseline U-Net and our pose-aware training approach under realistic intraoperative conditions where patient pose is variable and uncontrolled.

**Bio.** Chou (Athena) Mo is a rising junior at the University of California, Los Angeles, majoring in Mathematics of Computation. Previously, she has worked on deep learning for human pose recognition, developing a hybrid CNN-Transformer model to classify dynamic movement patterns in Tai Chi. She has also been the programming lead for the UCLA University Rovers Challenge team, where she led the development of autonomous computer vision tasks and motion control for a 6-DOF robotic arm.

**Assessing Alterations in Thalamic Fiber Integrity After Temporal Lobe Epilepsy Resection: Impact of Clinical Factors**

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[3]*Department of Neurological Surgery, Vanderbilt University Medical Center*

The thalamus plays an important role in spreading seizures in temporal lobe epilepsy (TLE). For patients with drug-resistant TLE, surgical removal of the epileptogenic focus—either through selective amygdalohippocampectomy (SAH) or anterior temporal lobectomy (ATL)—can reduce seizures. However, how these surgeries affect the thalamus's structure remains unclear. In this study, we used advanced MRI techniques to investigate changes in thalamic nerve fiber integrity from surgery and examined whether factors such as surgery type, time since surgery, and duration of epilepsy influenced these changes. We analyzed brain scans from 30 healthy controls and 44 TLE patients (30 with right-sided epilepsy) who underwent SAH (n=34), or ATL. Patients were scanned before and after surgery, while controls were scanned once. Using a method called *fixel-based analysis*, we measured fiber integrity in the thalamus by analyzing microscopic changes in water diffusion along nerve pathways. Results showed that thalamic fiber integrity declined after surgery, particularly in the thalamus's ventral and pulvinar regions on the same side as the surgery. Longer time after surgery led to further decreases in these areas. ATL (a larger resection) caused greater fiber integrity loss than SAH, especially in right-sided epilepsy. Additionally, patients with longer duration of epilepsy showed weaker fiber integrity declines, possibly due to pre-existing damage. Our findings suggest that thalamic fiber integrity decreases after TLE resection, and this decrease escalates with larger surgeries and longer time after resection. These results may help identify new candidate targets for thalamic stimulation in TLE, although further work is necessary.

**Bio.** Kaiser Williams is a rising senior undergraduate majoring in Biomedical Engineering. He began working in the Morgan Lab in January 2024, and has since presented a poster at the American Epilepsy Society Annual Meeting and has participated in the VUSE Summer Research Program and Vanderbilt Institute of Surgery and Engineering (VISE) Summer Fellows Program. He was also awarded first place in the undergraduate category for his poster at the VISE Annual Symposium in December 2024. Kaiser hopes to attend medical school after graduating from Vanderbilt.

## 51 | Nicolas Poliak | VINSE NSF-REU

**Development of NiPp-PPAA Layer-by-Layer Drug-Coated Balloons to Inhibit p38/MK2 Signaling in Peripheral Artery Disease**

**Nicolas Poliak**[1,2], Avanelle Stoltz[2], Jack Kujawski[2], Jahnu Saikia[2], Craig Duvall[2]
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Peripheral artery disease (PAD) can be treated with balloon angioplasty wherein a ballon is inserted to a site of blockage and then inflated to open the narrowed vessel site. These sites unfortunately restenose, or re-narrow, ~60% of the time within a year. This is at least partly driven by balloon injury stimulating vascular smooth muscle cells (VSMCs) in the artery to take on a proliferative, synthetic phenotype. Cytotoxic paclitaxel-eluting balloons are used to indiscriminately kill proliferating cells, but they also impair endothelial repair and may cause thrombosis. We engineered a non-cytotoxic drug-coated balloon (DCB) that deploys a cationic Niban-derived phosphomimetic peptide (NiPp) to inhibit the VSMC phenotypic change while sparing the endothelium. NiPp was electrostatically loaded with anionic poly(propylacrylic acid) (PPAA) in a layer-by-layer manner using coating solutions with varied NiPp concentration, lactosucrose (LS) excipient, and number of alternating PPAA/NiPp layers. Peptide loading and release were quantified before selected formulations were then deployed for testing ex vivo in rat aortas. Loading increased with both NiPp concentration and layer number, whereas LS augmented dispersion of the peptide into the arterial wall upon DCB deployment. The highest surface loading (4.91 μg/cm$^2$) and near-complete burst release (94.5%) were obtained with the 12-bilayer, LS-free formulation. This lead candidate provides the best balance of coating mass, rapid release, and preliminary ex vivo retention. Further studies will investigate tissue uptake and ability of this treatment to prevent SMC phenotype switching and restenosis, while allowing endothelial repair at angioplasty sites.

**Bio.** Nicolas Alejandro Poliak is a first-year student at Johns Hopkins University pursuing dual B.S. degrees in Chemical & Biomolecular Engineering and Applied Mathematics & Statistics. Raised in Miami, Florida, he is driven by the potential of nanobiotechnology to reshape drug delivery systems and enable entirely novel classes of therapeutics. Poliak began his research career at Johns Hopkins, assisting on peptide-based drug-delivery projects that deepened his interest in nanoscale carriers and controlled release strategies. In summer 2025 he joined Dr. Craig Duvall's Advanced Therapeutics Laboratory at Vanderbilt University (VINSE REU), where he engineered a layer-by-layer drug-coated balloon loaded with a phosphomimetic NiPp peptide to inhibit the p38/MK2 pathway responsible for restenosis after peripheral angioplasty. His contributions span polymer surface modification, fluorescence-based loading and release analytics, and preliminary ex vivo vascular transfer studies.His technical interests encompass diffusion-controlled drug release, peptide and polymer therapeutics, and nanoparticle platforms for targeted delivery. Poliak intends to pursue graduate studies, and ultimately an academic career, focused on developing next generation nanobiotechnologies that offer safer, more effective treatments for cardiovascular and oncologic diseases. Beyond the laboratory he enjoys experimenting with new recipes, mechanical watch making, and exploring both contemporary and classic literature.

**Assessing the Ability of a Nanobody–Drug Conjugate to Reprogram Regulatory T Cells**

**Azeeza S. Syeda**[1], Anastasia K. Varanko[2], John T. Varanko[2]
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[2]*Department of Chemical and Biomolecular Engineering, Vanderbilt University, Nashville, TN, USA*

Immunotherapies have transformed cancer treatment, yet their efficacy remains limited by the immunosuppressive tumor microenvironment. Regulatory T cells (Tregs) are key contributors to this suppression, making them critical targets for improving anti-tumor immunity. Recent studies show that activation of the Stimulator of Interferon Genes (STING) pathway using the agonist diABZI can reprogram Tregs into inflammatory, effector-like cells. To explore this potential treatment paradigm, we developed a nanobody–drug conjugate platform to deliver diABZI directly to Tregs and activate the STING pathway with greater specificity. After purifying the proteins from *E. coli expression* cultures, we conjugated them to diABZI via copper-free click chemistry. These conjugates were tested in both *in vitro* Treg reprogramming assays and *in vivo* tumor models to evaluate their capacity to reduce Treg-mediated immunosuppression and boost anti-tumor immunity. Our preliminary findings suggest that in mice, treatment with AC-diABZI led to a measurable slowing of tumor growth, indicating that targeted STING activation in Tregs may effectively mitigate their suppressive function and enhance overall anti-tumor responses.

**Bio.** Azeeza Syeda is a rising junior and Cornelius Vanderbilt Scholar at Vanderbilt University, majoring in Medicine, Health, and Society. She conducts research in Dr. John Wilson's lab, focusing on nanobody–drug conjugates for immune modulation with potential applications in cancer immunotherapy. As Head Resident Advisor, she mentors underclassmen and helps lead residential programming. She also serves as a Conferences and Events Lead, supporting the planning and execution of major university events. Azeeza contributes to the Vanderbilt Undergraduate Research Journal and is actively involved in the Students for Medical Humanities organization, reflecting her commitment to integrating science with humanistic perspectives. She aspires to pursue an MD/PhD, combining clinical practice with biomedical research to advance health equity. In her free time, she enjoys creative writing, cooking, and exploring Nashville.

**Neuro-symbolic KenKen Solver and VLM Evaluation**

**Kiersten Brennan**
*Vanderbilt University School of Engineering*

As transformer-based artificial intelligence (AI) progresses from textual to multimodal applications, they are becoming increasingly skilled at complex reasoning tasks. However, due to their deep architecture and non-deterministic nature, vision-language models (VLMs) struggle with explainability and tasks requiring step by step thinking. In comparison, neuro-symbolic AI categorizes models that leverage both human logic and neural networks for interpretable results. This project proposes a neuro-symbolic model that chains together convolutional neural networks (CNNs), computer vision (CV) techniques, and the Z3 satisfiability modulo theories (SMT) solver to solve KenKens, which are sudoku-like math puzzles. Z3 efficiently solves complex symbolic puzzles by encoding them as logical formulas and navigating the solution space using constraint-satisfaction and backtracking. Provided an empty puzzle board, solving a KenKen requires image decomposition, mathematical computation, and trial and error, making it a relevant benchmark for VLMs. This project generates and evaluates models on a dataset of 100 KenKen puzzles for 5 different grid sizes ranging from 3 to 7, where difficulty increases with grid size. The neuro-symbolic model achieves 100% accuracy on sizes 3-6, dropping to 93% accuracy for 7x7 puzzles. Four state-of-the-art (SOTA) VLMs were evaluated: Gemini-2.5-Pro, GPT-4o-mini, Claude Sonnet 4.0, and Qwen2.5-VL-7B-Instruct. Gemini achieved the highest VLM accuracy with 77% for 3x3 puzzles and 30% for 4x4s. None of the VLMs were able to solve a 5x5 puzzle from the dataset. Investigating the VLM responses further revealed frequent image misinterpretations, pointing to difficulty aligning complex reasoning with visual understanding. The results demonstrate that in addition to shorter training and response time, the customized neuro-symbolic approach outperforms VLMs while offering an explainable solution.

**Bio.** Kiersten Brennan is a rising Sophomore at Vanderbilt University School of Engineering studying Computer Science and Applied Mathematics. She is currently involved as a developer in Change++ and a member of Kappa Theta Pi Technology Fraternity. She has a background teaching high school students and working on independent projects related to data science and machine learning, and she has interned at the political non-profit Leadership Now Project. She is interested in web development and AI research with a focus on natural language processing.

**Imaging polaritons in real-time with step-scan nano-FTIR**

**Madeleine R. Adams**[1], Jeb Buchner[2], Mingze He[3], Joshua D. Caldwell[4]
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[2]*Interdisciplinary Materials Sciences Program, Vanderbilt University, Nashville, TN*
[3] *Department of Physics, City University of New York, New York, NY*
[4]*Department of Mechanical Engineering, Vanderbilt University, Nashville, TN*

Polaritons are quasi-particles formed through the coupling of an oscillating charge and light and are commonly analyzed with scattering-type scanning near-field optical microscopy (s-SNOM) and nano-FTIR. While s-SNOM and nano-FTIR provide spatial mapping of the IR response of materials with sub-20-nm spatial resolution, one significant limitation of these techniques is the inability to record time-resolved polariton imaging to track generation and interference phenomena. A recent paper addressed this challenge by using nano-FTIR to generate time-resolved images of polariton propagation via a step-scan approach. The aim of this poster is to demonstrate the implementation of the time-dependent imaging method developed in that paper on low-symmetry, highly anisotropic polaritonic crystals. The fabrication methods developed for this work involved photolithography and a bright-field photomask with several launcher shapes, including circles, rectangles, and crescents. Nano-FTIR measurements were taken of a calcite substrate with a gold disk polariton launcher for increasing time delays. The data processing method used was also developed during this effort, based on the prior work, enabling us to produce time-resolved images of so-called "Ghost" polaritons. The polariton propagation observed in the time-resolved images matched the expected hyperbolic propagation pattern. Next steps are to apply this time-resolved imaging method to highly anisotropic materials, such as bGO, where hyperbolic shear effects cause the polariton to rotate on the surface as a function of incident frequency, and exhibits highly anisotropic wavefronts.

**Bio.** Madeleine Adams is an undergraduate mechanical engineering major at Vanderbilt University and is entering her junior year. She became interested in the work of the Caldwell Lab after taking Thermodynamics with Dr. Joshua Caldwell in the fall semester of her sophomore year. She has been with the Caldwell Lab since spring semester of her sophomore year and plans to continue with the Caldwell Lab after the summer program concludes. She will expand on the project she started this summer as she continues with the lab.

## 55 | Anna Elizondo | Chemical Biology NSF-REU

**Synthesis of Marrulibacetal via g-hydroxylation of Carvone**

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Diterpenoid lactones are a class of plant derived natural products that feature a 20-carbon backbone and a lactone ring. These compounds have demonstrated a range of bioactivities, including anti-inflammatory, antioxidant, and neuroprotective effects, making them attractive targets in medicinal chemistry. However, their complex polycyclic structures present significant synthetic challenges. Previous syntheses of these molecules involve lengthy routes. Additionally, some key transformations in these strategies lack regio- or stereoselectivity, limiting their practicality. This work aims to address these limitations by developing an efficient and scalable synthesis beginning with commercially available (S)-carvone. A key transformation in the route is the installation of a g-hydroxyl group on carvone via a vinylogous Mukaiyama O-nitroso-aldol reaction. To enable this transformation, the synthesis of the nitrosobenzene reagent was optimized. Following hydroxylation, a Steglich esterification is planned to advance the molecule toward lactone formation. Several ester analogs have been synthesized to explore strategies for constructing the lactone ring characteristic of diterpenoid lactones. The ability to construct this frame may facilitate broader biological studies and enable structural analog development.

**Bio.** Anna Elizondo is an undergraduate student pursuing dual degrees in chemistry and biology at the University of Texas at San Antonio. Her research focuses on organic synthesis and enzymology, with experience in steroid synthesis. Anna has conducted research at UTSA in projects involving copper-catalyzed borylation and the synthesis of 1b-hydroxytestosterone. She has presented at multiple national and regional conferences, including ABRCMS, SACNAS, and the Gulf Coast Undergraduate Research Symposium. Her work has been published in the Journal of Chemical Education and ChemRxiv. Beyond the lab, Anna is active in STEM outreach, serving as a mentor in the Rising Researchers program and volunteering with science education events in San Antonio.

**Contactless Surface-Based Registration for Image-Guided Surgery**

**T.R. Folk**[1,2], P.C. Cannon[2,3], R.J. Webster III[2,3]
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[2]*Vanderbilt Institute of Surgery and Engineering, Vanderbilt University, Nashville, TN*
[3]*Department of Mechanical Engineering, Vanderbilt University, Nashville, TN*

Image-guided surgery (IGS) enables surgeons to visualize subsurface anatomy and instrument position in real time, improving surgical precision during robot-assisted procedures. A critical component of IGS is registering the patient's anatomy to preoperative models within the surgeon's console. In our current system, this is accomplished by tracing the surface of the organ with the da Vinci robot's instrument tip to generate a point cloud, which is then aligned with a segmented anatomical model using surface-based registration techniques. However, this touch-based approach presents challenges. Robotic systems lack haptic feedback, and contact with the organ surface can deform soft tissue, compromising registration accuracy. To address these limitations, we developed a low-cost, contactless alternative using a time-of-flight distance sensor mounted to a custom 3D-printed housing. The sensor is optically tracked to record spatial positions while collecting surface distance measurements. These data streams are synchronized in 3D Slicer using PlusServer, producing a point cloud suitable for Iterative Closest Point (ICP) registration. We validated the system using a kidney phantom with known geometry. Our preliminary results demonstrate that the contactless system can reliably generate surface point clouds that register preoperative models to the phantom with a target registration error of approximately 8 mm. This work demonstrates the feasibility of using affordable, contactless methods to perform surface-based registration in image-guided surgery. By reducing reliance on costly commercial tools and minimizing tissue deformation during data acquisition, this approach has the potential to improve registration accuracy and accessibility in clinical and research environments.

**Bio.** Taylor R. Folk is a rising senior undergraduate student majoring in bioengineering at Harvard University. This summer, she is a Vanderbilt Institute for Surgery and Engineering Summer Research Fellow at Vanderbilt University, working in the Medical Engineering and Discovery Lab (MEDlab) under Dr. Robert J. Webster III. Her research focuses on developing a contactless registration method for image-guided surgery. After graduation, she plans to pursue a Ph.D. in biomedical or mechanical engineering.

## 57 | Sahpar Ozer | VINSE Tech Crew

**Thin, Fast, and Conductive: Production of Graphene Circuits for Education and Innovation**

**Sahpar Nil Ozer**[1,2], Christina McGahan[2]
[1]*Department of Mechanical Engineering, Vanderbilt University*
[2]*Vanderbilt Institute of Nanoscale Science and Engineering, Vanderbilt University*

Graphene's exceptional electrical, mechanical, and optical properties make it an ideal material for a wide range of applications. From electrical transport to medicine, electronics to defense, graphene is already transforming multiple industries, and this is only the beginning. Yet, its accessibility for students remains limited due to fabrication complexities. This project focuses on fabricating reusable electrical graphene devices that are both durable and suitable for outreach use among students of various age groups, with the goal of expanding both exposure to and accessibility of high-quality graphene for educational and experimental purposes. These devices are intentionally designed to demonstrate two of graphene's most compelling properties, its exceptional electrical conductivity and optical transparency, enabling learners to directly observe how an advanced material can be applied in functional and visually engaging technologies. By employing chemical vapor deposition (CVD) which decomposes methane gas to deposit graphene onto copper substrates in a cleanroom tube furnace, this project achieves reproducible, high-quality graphene growth verified through Raman spectroscopy and electrical testing. Over the summer, this project was started with growing graphene and fabricating simple resistor devices using aluminum electrodes to effectively highlight graphene's conductivity and transparency. More recently, a Cu test device with larger electrode pads was introduced to improve device durability and facilitate broader testing. Future work may explore flexible substrates such as parylene. These reusable devices will facilitate hands-on experimentation and outreach, providing practical tools to integrate graphene technology into educational settings and inspire ongoing innovation.

**Bio.** Sahpar Nil Ozer is a sophomore at Vanderbilt University pursuing a double major in Mechanical Engineering and Economics with Honors, alongside a minor in Nanoscience and Nanotechnology. Originally from Turkey, she is a member of the Cornelius Vanderbilt Scholars Program. Since Spring 2025, Sahpar has been part of the VINSE Tech Crew, where she supports researchers and continues to explore her growing interest in nanotechnology. Beyond academics, she is an active member of Delta Sigma Pi, professional business fraternity, and VFW. In her free time, Sahpar enjoys playing Go (Weiqi).

**Wearable Magnetic Actuation System for Smart Medical Stents**

**Timothy J Fang**[1], Miles Kim[1], Ruijian Ge[1], Xiaoguang Dong[1,2,3]
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[3] *Department of Electrical and Computer Engineering, Vanderbilt University, TN 37212, US*

Airway stents play a vital role in managing airway obstruction in patients with lung cancer. However, conventional stents often lead to excessive mucus accumulation and breathing difficulties. To address this challenge, previously we developed a smart ciliary airway stent actuated by a wearable magnetic system designed to actively transport mucus and reduce central airway obstruction. However, previously developed wearable magnetic actuation systems are too bulky and limited in magnetic field strength. Here, we present a compact, wearable magnetic actuation system featuring coordinated magnetic units capable of generating stronger and more effective magnetic fields to drive the motion of integrated magnetically actuated cilia within the stent. The system incorporates microcontrollers, motor drivers, motors, and other key components, and is adaptable for both human and sheep models. We demonstrated that the system could produce magnetic fields up to 23 mT at a distance of 4 cm. Through a series of tests, we analyzed the cilia movement patterns under various magnet rotation frequencies and orientations. Results revealed that using two actuation units with opposing orientations—angled to avoid pole-to-pole alignment—produces a circular ciliary motion that optimally thins and pumps mucus. Finally, we validated the effectiveness of the system in a trachea phantom, showing successful mucus clearance from the stent. This magnetic actuation system holds strong potential to improve airway stent performance by mitigating mucus accumulation and enhancing patient outcomes.

**Bio.** Timothy Fang is a third-year undergraduate student majoring in Mechanical Engineering at Vanderbilt University. He has been conducting research on soft robotics and medical devices in the VINSE-affiliated Miniature Robotics Laboratory under the instruction of Dr. Dong, during the Spring and Summer semesters of 2025.

## 59 | Shelby Jenkinson | Chemical Biology NSF-REU

**Thermal Destabilization of a Synthesized Mitoxantrone-DNA Duplex**

**Shelby M. Jenkinson**[1,2], Nourhan M. Abo Omar[2], Michael P. Stone[2]
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*[2]Department of Chemistry, Vanderbilt University, Nashville, TN, 37235*

Mitoxantrone is a synthetic cancer drug used against leukemia and solid tumors. Its cytotoxicity is believed to be due to interference with the enzyme topoisomerase II, which is required for cell division. Carmelo Rizzo and co-workers (Vanderbilt University) showed that mitoxantrone forms a Schiff base when bound to abasic sites (AP sites). The potential role of such conjugates in cytotoxic response is not known. This study focused on the synthesis of the mitoxantrone-DNA adduct and reduction of the Schiff base to stabilize the conjugate to compare its thermal stability to the respective unmodified DNA duplex. Methods used in this study include the synthesis of a mitoxantrone-DNA duplex using a 12-mer DNA sequence modified with the replacement of a guanine with a uracil and its unmodified complementary strand, incubation with uracil DNA glycosylase, followed by incubation with mitoxantrone and sodium cyanoborohydride. This product was purified by reverse-phase HPLC, desalting, and hydroxyapatite purification. Next, timed, temperature-controlled experiments occurred alongside UV-Visual spectroscopy to obtain heating curves of both the mitoxantrone-DNA duplex and unmodified duplex with close concentrations. The synthesis of the mitoxantrone-DNA duplex was confirmed by HPLC and MALDI-mass spectrometry. The melting temperature experiments provided heating curves in which the first derivative graphs showed a lower melting temperature for the mitoxantrone-DNA duplex in comparison to the unmodified DNA duplex. This shows lower thermal stability of DNA when mitoxantrone forms these DNA adducts. The lower stability may contribute to its cytotoxicity.

**Bio.** Shelby Jenkinson is an intern through the NSF Vanderbilt Chemical Biology REU. She is a senior at Trevecca Nazarene University double majoring in chemistry and biology with a minor in math. There she is a McClurkan scholar and a part of their American Cancer Society chapter, serving as their secretary last year. She has maintained a 4.0 and Dean's list recognition throughout her years at Trevecca. She serves as a teacher's assistant to three departments simultaneously: chemistry, biology, and math. She prepares solutions and laboratory materials and assists in leading laboratory classes for general biology courses. Shelby also grades calculus work and aids students in their studies as a tutor for chemistry, math, and physics.

## 60 | Miles Kim | VUSE Summer Research Program

**Wirelessly Actuated Self-Expandable Stent with Magnetic Artificial Cilia for Mucus Transportation**

**Miles Kim**[1], Timothy Fang[1], Yusheng Wang[1], Xiaoguang Dong[1,2,3]
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*[2] Department of Biomedical Engineering, Vanderbilt University, TN 37212, US*
*[3] Department of Electrical and Computer Engineering, Vanderbilt University, TN 37212, US*

Airway stents are vital medical devices used to treat lung diseases such as chronic obstructive pulmonary disease, lung cancer, and cystic fibrosis. However, traditional airway stents inhibit airway cilia function, leading to excessive mucus buildup. Here, we propose to integrate small-scale bio-inspired artificial cilia on airway stents to mitigate excessive mucus. Laser-cut cilia made of an NdFeB and EcoFlex 00-30 polymer composite can be adhered to the inside of a commercial metal stent and actuated by an external magnetic field to reduce mucus layer thickness and transport mucus out of the stent. A tunable magnetic field is provided via a wearable magnetic actuation system (WMAS), which offers three degrees-of-freedom on a rotating magnet. The magnetically actuated cilia successfully promoted mucus flow along the stent, reducing required magnetic field strength to 15 mT, which is a 60% improvement over the previous design.

The artificial cilia on the stent maintained consistent mucus-pumping performance during extended actuation over several days, as well as during dynamic testing under mechanical compression and strong airflow of up to 25 m/s, demonstrating strong durability and reliability. Therefore, the magnetically actuated ciliary airway stent is promising for facilitating mucus clearance in the airway of patients while maintaining long-term durability and safety. Additionally, the proposed stent and WMAS require lower magnetic field strengths than previous designs. This approach may potentially improve patient outcomes and enable safer, simpler solutions to mucus buildup in airway stents.

**Bio.** Miles Kim is a rising-sophomore undergraduate student in the Department of Mechanical Engineering at Vanderbilt University. He has been working as an undergraduate researcher on soft robots and magnetically actuated medical devices in the Miniature Robotics Laboratory lead by Dr. Dong since Spring 2025.

## 61 | Alexandra Lee | VUSE Summer Research Program

**Optimizing Sortase A Transpeptidase Reaction for Protein-Small Molecule Conjugation**

**Alexandra Lee**[1], Neil Chada[1,2], John T. Wilson[3]
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*2 Medical Scientist Training Program, Vanderbilt University School of Medicine, TN, USA*
*3 Department of Chemical and Biomolecular Engineering, Vanderbilt University, TN, USA*

Cancer immunotherapies are often less effective in solid tumors due to their immunosuppressive microenvironment; one approach to overcoming this barrier is to deliver immunostimulatory drugs directly to the tumor. This project focuses on testing a nanobody-drug conjugate (nAlb-diABZI) that targets albumin and is conjugated to the small molecule STING agonist diABZI, a part of which requires optimization of the enzyme-mediated ligation reaction used to produce it. An anti-albumin nanobody was site-specifically conjugated to diABZI using a two-step process: pentamutant sortase A-mediated ligation to append an azide group, followed by click chemistry with a modified DBCO-diABZI molecule. Reaction conditions were optimized by systematically adjusting buffer composition, temperature, incubation time, and molar ratios. The improved protocol more than doubled efficiency to approximately 55%, compared to less than 25% under previously used conditions. Product purity and successful conjugation were confirmed using UV-Vis spectroscopy, SDS-PAGE, and electrospray ionization mass spectrometry. In vitro assays using A549 and THP1 dual-reporter cells demonstrated that both free and nanobody-conjugated diABZI induced interferon expression, with greater sensitivity in THP1D cells. In vivo, treatment with nAlb-diABZI slowed tumor growth and improved the probability of survival more effectively than free drug or non-targeted controls in a subcutaneous neuroblastoma mouse tumor model, highlighting the potential of targeted STING agonist delivery in treating solid tumors.

**Bio.** Alexandra (Alex) Lee is a rising fourth-year undergraduate student majoring in biomedical engineering at Vanderbilt University, originally from Seoul, South Korea. She joined the Wilson Immunoengineering Lab in January 2024 and is interested in the development and testing of immunotherapies and biomaterials for cancer treatment. Alex was selected for the VUSRP cohort in 2024 and the VUSE Summer Research cohort in 2025. Alex is interested in pursuing a Ph.D. in biomedical engineering with the intent of working on cancer immunotherapies.

**Local Control of Ferroelectric Switching for Optical Modulation in $Al_{1-x}B_xN$**

**Adriana LaVopa**[1], Youngji Kim[2], Joshua Caldwell[2,3]
[1]*Department of Materials Science and Engineering, University of Florida*
[2]*Department of Mechanical Engineering, Vanderbilt University*
[3]*Interdisciplinary Materials Science, Vanderbilt University*

In the pursuit of space- and energy-efficient devices, nanophotonics offers an avenue towards controlling opto-electronic and optical signals far below the length scales of diffraction-limited technology. Key to achieving this sub-diffraction resolution in the infrared are polaritons, quasiparticles that arise from the coupled interactions between light and matter. A promising approach to harnessing polaritons for opto-electronic applications is modulating optical signals via tunable polaritonic materials. Ferroelectric materials present an opportunity to modulate polaritons via electronic bias due to their inherent polarization, which can be aligned to or reversed by an applied electric field. Aluminum boron nitride ($Al_{1-x}B_xN$) is one such ferroelectric material that has recently garnered attention for these uses due to its combination of suitable material properties and integrability into current device manufacturing methods. In this work, we employed local polarization switching using piezoresponse force lithography (PFL) to precisely pattern ferroelectric domains into $Al_{1-x}B_xN$. Piezoresponse force microscopy (PFM) and experimental and computational optical methods were applied to explore the potential of $Al_{1-x}B_xN$ as a polaritonic material for actively modulated optical emission. PFM revealed the voltage- and composition-dependence of the polarization response in $Al_{1-x}B_xN$, as well as the stability of the resulting domains over time. Experimental and computational spectroscopic results indicated that the polarization of $Al_{1-x}B_xN$ influences its interactions with infrared (IR) radiation, as well as polaritonic modes in an adjacent material, enabling control of an output signal via applied electric field at sub-second timescales. Our findings suggest that ferroelectric polarization in $Al_{1-x}B_xN$ offers an accessible means to modulate the optical response of an emitter in the IR spectral range, opening the door to applications in the information technology, IR free-space communications, chemical sensing, and thermal management devices of the future.

**Bio.** Adriana LaVopa is a rising fifth-year undergraduate at the University of Florida, majoring in Materials Science and Engineering with a minor in Linguistics. This summer, she is conducting research in Prof. Joshua Caldwell's Nanophotonic Materials and Devices Lab, under the mentorship of postdoctoral researcher Dr. Youngji Kim. Her past research experiences include protein-based synthetic biology (UF) and epitaxial growth of ferroelectric materials (Cornell University). She plans to pursue a Ph.D. in materials science and aims to build a career in research, with a focus on the intersection of materials design, discovery, and science communication.

**Synthesis of 2,2′-Dipyridyl(3-fluoroaryl)methane Ligands for sp$^3$ C–H Borylation**

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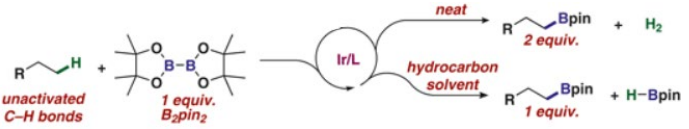
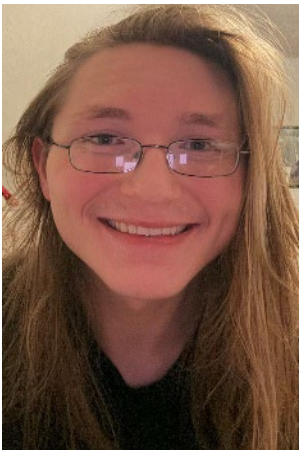



Dipyridylarylmethane ligands at the Schley lab have provided an effective catalyst system for the iridium-catalyzed borylation of alkyl C–H bonds. C–H borylation is a useful tool for synthetic chemists as organoboronate products have been utilized for their versatile reactivity. Substitutions around the ligand scaffold have helped improve the catalyst's ability to activate typically inactive sp$^3$ C–H bonds through an isolable ligand-bound iridium hydridoboryl complex. Under conditions with excess substrate, ligands have enabled an improved yield exceeding 1 equivalent of product formation from the generated HBpin byproduct. With near-limiting amounts of substrate in cyclic alkane solvent, these reactions only achieve the first equivalent of product formation. This summer, my work focused on the synthesis and characterization of several ligands, purifying them by column chromatography, and confirming their purity by NMR spectroscopy. Additionally, an effort was made in developing a method to purify the crude alkyl boronate products for isolated yields. Ongoing research is aimed at synthesizing further ligand variants and evaluating performance through more catalytic trials in hopes of developing a more active catalyst system for a broader substrate scope.



**Bio.** Griffin is an incoming junior transfer student to the University of Tennessee at Chattanooga. He graduated from Motlow State Community College with an associate's degree in chemistry.

**A Wearable Extracorporeal Membrane Oxygenation System for Safer Patient Ambulation**

***Lawrence Li***[1], *Sriya Bapatla*[1], *Gabriella Glomp*[1], *Colleen Burke*[1], *Rei Ukita*[1,2]

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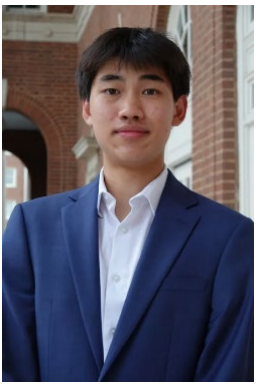
Extracorporeal membrane oxygenation (ECMO) is a life-support system for patients with severe heart or lung failure. By draining venous blood from the patient, pumping it through an oxygenator, and returning oxygenated blood to the body, ECMO helps patients maintain adequate oxygenation while awaiting organ transplants. Though patients are traditionally sedated, newer studies suggest that ambulating patients on ECMO helps maintain their strength, reduce hospital stay, and improve lung transplant outcomes.[1] However, current ECMO machines are large and heavy, often requiring several staff to move a single patient.[2]

To address this, we developed a wearable 3D-printed ECMO pump console weighing under 2 kg—compared to traditional systems that weigh over 10 kg. Our modular design includes a motor casing and a "twist-to-lock" cap to secure the pump, allowing for universal pump compatibility. Our lightweight pump serves as an alternative to clinical ECMO consoles, allowing patients to exercise on ECMO.
We tested the system using a glycerol-based fluid that mimics blood, assessing whether it could achieve clinical flows and pressures (>4 L/min and >250 mmHg). The pump met these targets and operated for at least 6 hours without failure. Power consumption needs were also measured to guide future battery selection. Hemolysis tests were performed to assess safety of the console.

This work is a promising step toward wearable ECMO technology that could help critically ill patients regain mobility safely. Future work includes further hemolysis testing and full system integration with an oxygenator, tubing, batteries, and user interface into a wearable vest.



**Bio.** Lawrence is a junior at Vanderbilt University studying Biomedical Engineering. He is particularly interested in life support systems such as mechanical ventilation and extracorporeal membrane oxygenation. His ultimate goals are to be a clinician one day and implement the devices and systems he works on with his engineering background. In his free time, he enjoys tennis, playing the drums (poorly), talking to his little brother, and exploring new places with friends. He can be reached at lawrence.w.li@vanderbilt.edu.

[1] Kourek C, Nanas S, Kotanidou A, Raidou V, Dimopoulou M, Adamopoulos S, Karabinis A, Dimopoulos S. Modalities of Exercise Training in Patients with Extracorporeal Membrane Oxygenation Support. J Cardiovasc Dev Dis. 2022 Jan 20;9(2):34. doi: 10.3390/jcdd9020034. PMID: 35200688; PMCID: PMC8875180.

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## 65 | Caroline Yao| VUSE Summer Research Program

**Short-to-Long Leg X-Ray Prediction in Total Knee Arthroplasty**

**Zheye Caroline Yao**[1,2,4], Yehyun Suh[1,2,3], J. Ryan Martin[5], and Daniel Moyer[1,2,3]

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We present two deep regression frameworks for inferring full-leg pose information from short-leg radiographs, a task critical to all stages in total knee arthroplasty. First, we develop a 2D regression model with ResNet backbone followed by dense layers that predicts the relative angular displacement of the femur and tibia with respect to the knee joint, given a short-leg post-operative image and associated anatomical landmarks. We demonstrate that this model outperforms 2D point-set registration methods using the Kabsch-Umeyama algorithm and the baseline predictor. Second, we extend the conceptual framework to 3D, training a separate neural network to infer the relative rotation between the reference and rotated images using a modified ResNet backbone with six input channels followed by dense layers. For in-plane rotations, the model regresses directly to a scalar rotation angle, while for axis rotations, it predicts the rotation itself expressed in terms of quaternions. We evaluate both tasks under patient-held-out and knee-held-out scenarios. Empirical results show that our model achieve high accuracy in the knee-held-out setting and satisfactory performance in the patient-held-out case.

**Bio.** Zheye "Caroline" Yao is a rising senior at Swarthmore College, where she is an honors major in mathematics and honors minor with course major in computer science. Her research interests span machine learning and theoretical computer science. She has conducted research in multiple areas, including computational geometry, query complexity theory, and algorithmic fairness. She was a Frances Valey Science Research fellow and is a member of the Sigma Xi Swarthmore Chapter.

Outside of academics, she is active in competitive programming. Her team received a Mid-Atlantic Regional Silver medal in 2023-2024 and won the Eastern Pennsylvania Championship with a Gold Medal in the 2024-2025 season. At Swarthmore, she also engages in teaching and departmental service, serving as teaching assistants for various math and computer science courses and as a student representative on the computer science department's advisory council. After graduation from Swarthmore, she plans to apply to graduate school to further her interests in math and computer science.

**Evaluating Anatomical and Diffusion Magnetic Resonance Imaging Methods for Application in the Thoracic Spinal Cord**

**Nathan Williams**[1,2], Alicia Cronin[2,3], Aimee Salakhov[2], Ryan Robison[2,3,4], Kristin O'Grady[1,2,3]
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[2]*Vanderbilt University Institute of Imaging Sciences, Vanderbilt University Medical Center*
[3]*Department of Radiology, Vanderbilt University Medical Center*
[4]*Philips*

Imaging the spinal cord is important for determining pathology and prognosis in people with multiple sclerosis (MS). Despite ample MRI methods for brain and cervical spinal cord imaging in research and clinical practice, imaging the thoracic section of the spinal cord remains challenging primarily due to its proximity to the lungs. We hypothesize that use of a "navigated" multi-echo fast field echo (mFFE) MRI sequence will improve signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) in thoracic spinal cord anatomical images. Additionally, we hypothesize that a multi-shot diffusion tensor imaging (DTI) sequence will improve image quality compared to its single-shot counterpart. For the former hypothesis, we imaged twenty healthy volunteers and three MS patients and applied the mFFE sequence with and without the navigator. After generating white matter and gray matter segmentation masks, we calculated SNR (for white and gray matter) and CNR for the navigated and non-navigated data. Diffusion data were acquired in three healthy volunteers. After denoising and motion correction, we extracted quantitative DTI maps, which provide information on tissue microstructure. DTI data for single-shot, two-shot, and three-shot sequences were qualitatively compared. Results for the mFFE experiment showed a statistically significant improvement in SNR and CNR for the navigated images. For DTI image comparisons, the multi-shot sequences resulted in less blurring and distortion, and improved tissue contrast. These preliminary results suggest that the navigated mFFE and multi-shot DTI sequences are useful in imaging the thoracic spinal cord, and these methods should be employed and improved upon in future studies.

**Bio.** Nathan Williams is an undergraduate researcher at VUIIS who will graduate from Vanderbilt University in 2028. He is interested in MRI's role in showing the pathogenesis, prognosis, and treatment of multiple sclerosis.

## 67 | Jiale Chen | VUSE Summer Research Program

**Wireless tracking of a capsule robot for close-loop control and navigation**

**Jiale Chu[1],** Jacob Katona[1], Boyang Xiao[1], Xiaoguang Dong[1,2,3]
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*[3] Department of Electrical and Computer Engineering, Vanderbilt University, TN 37212, US*

Small-scale, magnetically controlled capsule robots have the potential to perform minimally invasive medical operation such as drug delivery, biopsy, and sensing, by navigating to hard-to-reach areas within the human body. However, tracking their 6-degree-of-freedom (6-DOF) positions and orientations is challenging for feedback control. Here we aim to develop a system for real-time, 6-DOF tracking of a magnetically actuated capsule robot to enable precise and closed-loop navigation. Our method utilizes an external robotic arm-based permanent magnet system for wireless actuation, while a separate array of magnetic sensors continuously senses the capsule's magnetic field. An optimization algorithm estimates the capsule's real-time position and orientation by minimizing the error between the sensor readings and magnetic model prediction, considering the magnetic interference from the actuation magnet. The system successfully tracked the capsule robot during crawling locomotion within a tissue-embedded intestinal phantom. Validation against a ground-truth stereo camera system demonstrated relatively high accuracy, with a translational and rotational root-mean-square errors of 2.48 mm and 7.61 degrees, confirming its capability for full 6-DOF localization. This work demonstrates that a magnetic sensor array can provide robust, real-time feedback for the closed-loop control of magnetic capsule robots and establishes a framework for future intelligent miniature robots capable of performing complex, targeted tasks such as drug delivery and biopsy deep inside the body. The ongoing work focuses on extending this framework by integrating an onboard camera for direct visual feedback and developing a wearable magnetic actuation system to translate this technology towards at-home therapeutic applications.

**Bio.** Jiale Chu is a visiting summer research fellow at the Vanderbilt Institute for Surgery and Engineering (VISE) and a rising senior pursuing a B.S. in Robotics at the University of Michigan – Ann Arbor, where he maintains a 4.0 GPA on the Dean's List. He also has a background in Electronics and Computer Engineering from Shanghai Jiao Tong University. His research interests include sensing, control, and communication in robotics. He is currently working as an Undergraduate Research Fellow in Miniature Robotics Laboratory leaded by Dr. Dong.

## 68 | Jocelyn Leal | Chemical Biology NSF-REU

**Investigating the Effects of Human Milk Oligosaccharides on Biofouling**

**Jocelyn Leal**[1,2], Julie Talbert[2], Steven Townsend[2]
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Human Milk Oligosaccharides (HMOs) are the third most abundant macromolecule in human breast milk and have been proven to have antibiofilm properties. To investigate these properties further, we wanted to leverage the antiadhesive property of HMOs against boat biofouling, which is the buildup of bacterial biofilms on the bottom of ship hulls. This buildup provides the foundation for attachment of other macrofoulers (barnacles, muscles etc.), causing decreased speeds and expensive damages. After HMO isolation from whole breast milk samples, we first tested the leeching capabilities of HMOs out of the paint using NMR and TLC data. We found that the HMOs were stationary in the paint over three weeks. Second, we tested to see if the HMOs maintained their antibiofilm properties in ocean water by utilizing toy boats covered in paint with either no additive, HMOs, or cuprous oxide, the current, however toxic, standard for anti-fouling. Due to the large variability of our ocean water sample, we were unable to see any clear biofilm formation on the boats themselves, and the amount of matter in the specific water samples themselves increased from control to experimental groups. To properly test for biofilm formation in the future, it would be better to build an "ocean" inoculated with specific bacteria to ensure the buildup of biofilm and more conclusive results.

**Bio.** Jocelyn Leal is entering her senior year of undergrad at Haverford College, where she is pursuing a major in chemistry with a biochemistry concentration and a minor in health studies. At Haverford, she was recently hired as a Co-Head of Residential Life, and last summer she received the Frances Velay Women's Science Research Fellowship to pursue an internship with the Drexel Food Lab. Outside of science she is also on the varsity softball team at Haverford, where she has been honored with two consecutive Academic All-District awards. She is currently conducting research in Dr. Steven Townsend's Lab under PhD candidate Julie Talbert on the anti-bacterial and anti-biofilm properties of HMOs. In the fall, she will begin her thesis work in the lab of Dr. Yiming Wang doing research on nanoclusters as electrochemical sensors.

## 69 | Isabelle Gunawan | VU Undergraduate Summer Research

**Robotic Arm Sorting with Real-Time Machine Learning and Vision**

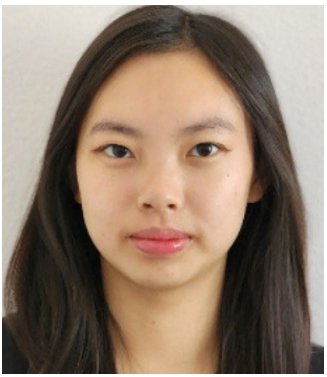
**Isabelle Gunawan**[1,2], Yayun Du[1,3]
[1]*Vanderbilt Institute for Surgery and Engineering, 1211 21st Ave S Suite 220, Nashville, TN*
[2]*Vanderbilt University, Department of Computer Science, Nashville, TN*
[3]*Department of Electrical and Computer Engineering, Vanderbilt University, TN*

This project investigates the development of a machine-learning-driven robotic sorting system designed to classify and organize objects on a conveyor belt in real time. The primary goal is to demonstrate how combining computer vision with robotic manipulation can automate tasks typically performed by human operators.

We implement a convolutional neural network trained on a dataset of 1,200 labeled images spanning five object categories. The camera stream is processed in real time to detect and classify items, then pass coordinates to a six-axis robotic arm which executes pick-and-place actions. The system uses TensorFlow for training and OpenCV for live image processing, while ROS (Robot Operating System) handles communication between vision and actuator components.

Our results show the model achieves 94% classification accuracy on test data and maintains a sustained sorting rate of 30 items per minute during continuous operation. Error analysis identifies that misclassifications occur primarily for objects partially occluded or with reflections. Despite this, the robotic arm reliably achieves 97% successful grasps, with the few failures traced to object slippage rather than vision errors.

In conclusion, this work demonstrates that integrating machine learning with robotic manipulation can achieve accurate and efficient automated sorting in a controlled environment. These findings suggest the approach is well-suited for industrial settings where repetitive sorting is required. Future work will focus on improving robustness under variable lighting and introducing adaptive grasp planning. This project is relevant to professionals interested in robotics, AI, and automation, and highlights how interdisciplinary techniques can be applied to practical engineering challenges.



**Bio.** Isabelle Gunawan is a rising sophomore at Vanderbilt University who is currently pursuing a major in Computer Science and a minor in Data Science.

**Measuring the Geometry of Neuronal Fibers in the Brain**

**Catherine Mao**[1], Adam Anderson[2]
[1]*Vanderbilt University, Department of Biomedical Engineering, Department of Neuroscience*
[2]*Vanderbilt University, Department of Biomedical Engineering, Vanderbilt University Institute of Imaging Science.*

Understanding the orientation and organization of axonal fibers in the brain is critical for validating MRI-based tractography and advancing knowledge of neural connectivity. This study presents a computational approach to analyze 3D confocal microscopy images and estimate fiber orientation using structure tensor analysis. Each z-stack image is divided into 3×3 sub-tiles, followed by preprocessing steps including intensity detrending, 3D deconvolution, and anisotropy correction. Gradients in x, y, and z directions are computed and used to construct 3×3 structure tensors per voxel, whose eigen decomposition yields the tertiary eigenvector ($e_3$), indicating local fiber orientation. Orientation vectors are scaled for tissue shrinkage and filtered using the planar Westin index and hysteresis masking to ensure high-certainty voxels. The resulting fiber orientation fields are further compared to the anatomical location of each tile within the brain to assess regional alignment. Additionally, fiber bundles aligned with 282 approximately uniformly distributed directions were identified, and fibers within each bundle were classified by visualizing 3D masks of the aligned voxels. This framework provides a robust reference dataset for validating diffusion MRI fiber models and supports spatially resolved anatomical studies of axonal architecture.

**Bio.** Catherine Mao is a junior at Vanderbilt University majoring in Biomedical Engineering and Neuroscience, with a minor in Data Science. Her research interests lie in the intersection of computational neuroimaging, brain microstructure, and data-driven analysis of neural tissue. She is a research intern in the Anderson Lab, where she developed MATLAB tools to analyze 3D confocal microscopy images and extract axonal fiber orientations using structure tensor analysis. She also conducts spike cross-correlation analysis in the Constantinidis Lab to study neuronal connectivity during working memory tasks in non-human primates.

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