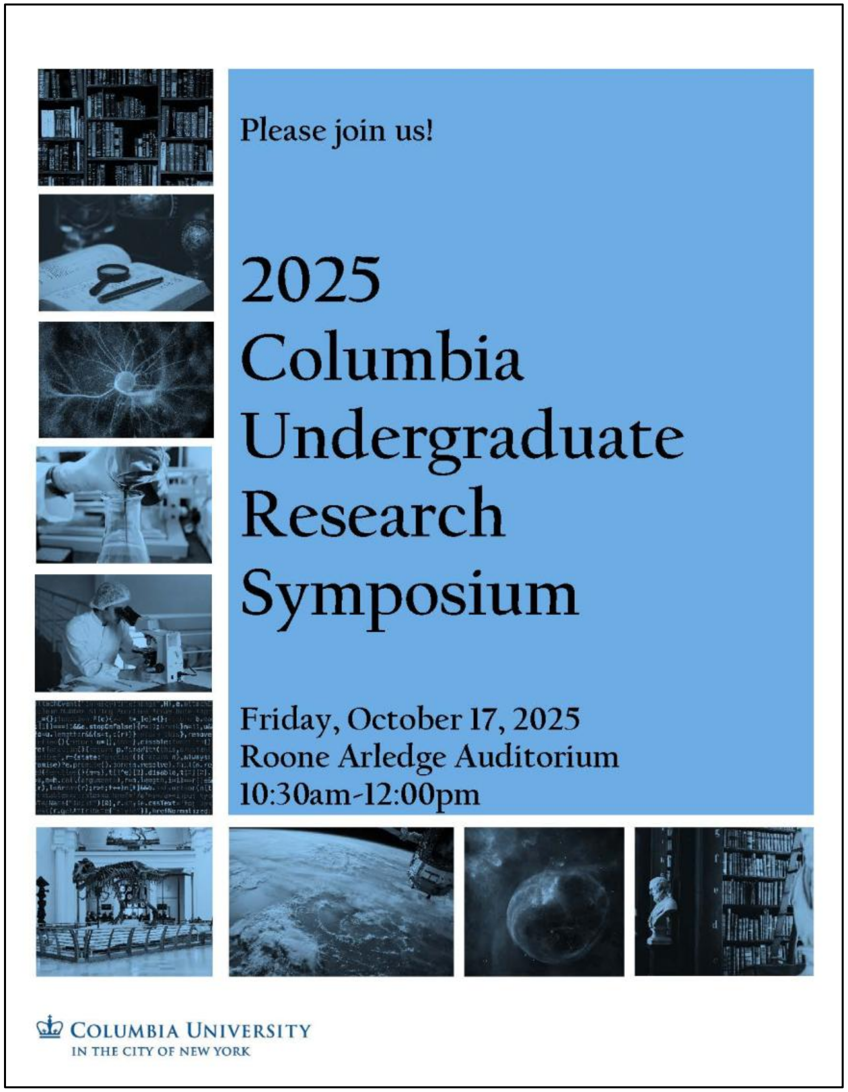

RESEARCH SYMPOSIUM 2025
Research Abstracts:

Aruzhan Abil CC'28, Computer Science, Mathematics, Amber Li CC'27, Computer Science, Mathematics-Statistics, Juno Marques Oda CC'27, Applied Mathematics

Faculty Mentor(s) or Supervisor(s): George Dragomir
Title: Structure Over Signal: A Globalized Approach to Multi-relational GNNs

Abstract: In financial markets, Graph Neural Networks have been successfully applied to modeling relational data, effectively capturing nonlinear inter-stock dependencies. Yet, existing models often fail to efficiently propagate messages during macroeconomic shocks. In this paper, we propose OmniGNN, an attention-based multi-relational dynamic GNN that integrates macroeconomic context via heterogeneous node and edge types for robust message passing. Central to OmniGNN is a sector node acting as a global intermediary, enabling rapid shock propagation across the graph without relying on long-range multi-hop diffusion. The model leverages Graph Attention Networks (GAT) to weigh neighbor contributions and employs Transformers to capture temporal dynamics across multiplex relations. Experiments show that OmniGNN outperforms existing stock prediction models on public datasets, particularly demonstrating strong robustness during the COVID-19 period.

Luca Abu El-Haj CC'26, Physics

Faculty Mentor(s) or Supervisor(s): Colin Hill
Title: Localized features in the polarization of the cosmic microwave background as a probe for inflationary physics

Abstract: Cosmic inflation was first proposed in the late 1970s by Alan Guth and Andrei Linde as a self-consistent solution to gaps in the standard model of cosmology. The theory of inflation posits that early in our universe's history, there was a period of rapidly accelerated expansion. Unlike late-time physics, inflation generates correlated fluctuations of temperature and polarization in the cosmic microwave background(CMB), differing only by their respective transfer functions. This work considers a model with a very massive particle present during inflation. Due to the extreme mass of the particles, they can induce gravitational potentials which when evolve forward

in time to be hot- and cold- spots in the CMB. The search for these particle hotspots, from a data analysis perspective, is similar to that of searches for galaxy clusters in the CMB, and has been explored in the CMB temperature data. This work adapts both the theoretical and analysis procedures to the polarization of the CMB, applying it to the data from the Planck Telescope, and deriving new constraints on physical models involving very massive particles during inflation. This work also forecasts the constraining power of the Atacama Cosmology Telescope, and for an idealized future telescope, and shows the dominance of this localized profile search as opposed to more conventional correlation function techniques.

Max Accurso SPS'26, Psychology, Madeline Galloway CC'27, Neuroscience and Behavior, Oscar Manuel Landa Samano CC'26, Psychology, Statistics, Catherine Lily Thomas BC'28, Psychology

Faculty Mentor(s) or Supervisor(s): Sarah Ashcroft-Jones
Title: Framing Climate Change: Loss vs. Gain Messages in a 26-Country Study

Abstract: Climate change communication often relies on framing strategies to encourage public engagement, yet the relative effectiveness of loss- versus gain-framed messaging remains contested. This study tested how message framing influences climate-related perceptions and behaviors across 26 countries. In an online experiment ($N \approx 10{,}400$), participants were randomly assigned to read either a loss-framed message (emphasizing damages caused by failure to mitigate climate change) or a gain-framed message (emphasizing benefits achieved through climate change mitigation). This experiment assessed perceived severity of climate change, self-reported intentions to learn more about mitigation, and actual information-seeking behavior (clicking a link for further resources). Consistent with the preregistered hypotheses, loss framing increased perceived severity, heightened intentions to seek information, and modestly boosted behavioral follow-through compared to gain framing, controlling for baseline attitudes. Mediation analyses further showed that climate emotions, particularly heightened anxiety and reduced hope, partially explained framing effects. This large-scale, cross-national design highlights the robustness and limits of framing as a climate change communication tool, revealing consistent patterns across diverse sociocultural contexts. The findings contribute to both theory and practice in climate communication, suggesting that while loss-framed appeals may generate stronger concern and interest, the emotional pathways warrant careful ethical consideration. These results can inform policymakers, NGOs, and communicators aiming to design impactful global climate messages.

Andre Adonnino CC'26, Biochemistry

Faculty Mentor(s) or Supervisor(s): Anthony Orneta
Title: The Pediatric Coping Plan: A Pilot Screening Tool to Elevate Emotional Care in Pediatric Emergency Medicine

Abstract: The Pediatric Coping Plan (PCP) is a pilot screening tool designed to identify and address the unique needs of children within the emergency department (ED) at a large academic urban hospital. Patients are screened using a REDCap screener containing a brief three-question survey to assess behavioral, emotional, and/or communication challenges, as well as past negative anesthetic experiences. The need for a personalized coping plan is indicated by the presence of one or more concerns. If a child screens positive, a coping plan is designed in real time using additional information gathered from the child and caregiver pertaining to triggers, communication/comfort, unsafe behaviors, and medications. These coping plans raise awareness of a child's concerns to medical staff, facilitating more personalized, comfortable care in the ED. Between July 2 and July 31, 2025, 125 patients were screened, with 29.6% ($n = 37$) screening positive and over 35 coping plans created. The most common indications were fear of a specific procedure ($n = 12$), sensory sensitivities ($n = 11$), and autism ($n = 9$). Screening took an average of 9 minutes to complete. Incorporated comfort strategies frequently overlapped between patients, including family presence and gentle touch. Trigger minimizers also overlapped, including a preferred distraction method and family presence. These results suggest the PCP has significant potential as a scalable intervention to proactively support pediatric patients' safety and trust in medical providers. This study suggests that the PCP may be a strong step toward elevating emotional care to the same priority as physical care.

Harun Afza CC'27, Psychology

Faculty Mentor(s) or Supervisor(s): Usha Barahmand
Title: Psychological Cascades of Childhood Trauma: The Role of Maladaptive Self-Processes in Borderline Personality Disorder

Abstract: Borderline personality disorder (BPD) is characterized by emotional instability, disturbed self-image, and self-harm, often rooted in childhood trauma. The mechanisms by which trauma leads to BPD symptoms are not fully understood. This study aimed to test a serial mediation model in which

maladaptive self-processes—self-criticism, anger rumination, and self-harm—mediate the relationship between childhood trauma and BPD symptoms. A community sample of 247 adults (mean age = 30.5 years; 64.4% female) was recruited online. Participants completed validated self-report measures: the Childhood Trauma Questionnaire, Levels of Self-Criticism Scale, Anger Rumination Scale, Self-Harm Inventory, and Borderline Symptom List-23. Data were analyzed using Pearson correlations and Hayes' PROCESS macro (Model 80) for serial mediation, with 5,000 bootstrap samples and bias-corrected confidence intervals. Childhood trauma was positively correlated with self-criticism, anger rumination, self-harm, and BPD symptoms. The mediation model accounted for 58.45% of the variance in BPD symptoms. Both direct and indirect effects of childhood trauma on BPD symptoms were significant. Self-criticism and self-harm were the strongest mediators. The sequential mediation pathway—from trauma to self-criticism, to anger rumination, to self-harm, and finally to BPD symptoms—was statistically significant. Findings support that maladaptive self-processes are critical psychological cascades linking early adversity to BPD. Interventions targeting self-criticism and anger rumination may help prevent the progression from trauma to self-harm and BPD symptoms. Limitations include the cross-sectional design and reliance on self-report. Longitudinal research is needed to confirm these pathways and inform trauma-focused interventions.

Yara Aguilar SEAS'28, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Santiago Correa
Title: Analysis of extracellular vesicle stability for their biofunctionality in supramolecular hydrogels

Abstract: Hydrogels, cross-linked networks of macromolecules that retain water, are biomaterials optimal for a variety of biomedical applications. Compared to more common formulations of hydrogels that are chemically modified, a class called supramolecular hydrogels are injectable expanding the range of their uses. The Correa Lab at Columbia University formulates hydrogels with modified naturally occurring cellulose polymers and various nanoparticles with lipid membranes. One of these nanoparticle types, extracellular vesicles (EVs), are nano-sized vesicles excreted from all cell types and carry molecules that facilitate communication between cells. EVs can be used to formulate supramolecular hydrogels that are natural and more intrinsically biologically active than those made with synthetic lipid nanoparticles. In previous studies, hydrogels with agriculturally-derived yogurt EVs have been shown to have potential for safe injection both in vitro and in vivo, even promoting vascularization. Utilizing agriculturally derived EVs in materials such as hydrogels is relatively new to the immunoengineering field, resulting in a knowledge gap of the properties of these EVs when incorporated into materials, especially when it comes to their functionality over time. This study focuses on the stability of yogurt EVs over 7 days, looking into their size, charge, and protein concentration following isolation through tangential flow filtration from bovine milk whey. Characterization is done through dynamic light scattering, nanoparticle tracking analysis, and bicinchoninic acid assay. Results indicate relatively small changes in both size and charge but stability in protein concentration over 7 days, thus providing more information on these new and versatile supramolecular hydrogels.

Ushrat Ahmed CC'27, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Christine Denny, Rebecca Ravenelle
Title: 5-HT4 receptor activation mediates the impact of late-life depression on age-related cognitive decline

Abstract: Adults aged 65 years and older are at high risk for late-life depression (LLD) which is often associated with cognitive impairment. Current treatments for depression have limited efficacy in the older population highlighting a need for novel therapeutics. The serotonin type 4 receptor (5-HT4R) has recently been identified as a therapeutic target for depression and cognitive decline. We have previously shown that prophylactic administration of prucalopride, a 5-HT4R agonist FDA approved for chronic idiopathic constipation, protects against depressive-like behaviors in adult mice. Here, we evaluated the efficacy of prucalopride to improve cognition and depressive-like behaviors in aged mice. Male mice (22-24-months-old) underwent learned helplessness (LH) stress. Mice were then administered prucalopride (1.5 mg/kg, i.p.) or saline for 14 days. Following drug administration mice underwent a LH test to gauge helplessness behavior, the forced swim test (FST) to assess behavioral despair, and the novel object recognition test (NOR) to assess working memory. Prucalopride treatment improved both behavioral despair and cognition compared to controls. As 5-HT4Rs are expressed on astrocytes, we used immunohistochemistry to analyze tissue for glial fibrillary acidic protein (GFAP), a marker of astrocyte reactivity, to determine if prucalopride treatment alters GFAP activity. Our preliminary results find that prucalopride increased GFAP expression in the anterior cingulate area (ACA) and prelimbic cortex (PL) of the medial prefrontal cortex compared to saline treated controls. These findings provide

important insight into a potential mechanism underlying the efficacy of 5-HT4R activation to improve behavioral outcomes in aged cohorts.

Ava Aimable CC'26, Psychology

Faculty Mentor(s) or Supervisor(s): Jereon van Baar
Title: Uncertain Times: Rising in the Intolerance of Uncertainty in the last Decade

Abstract: The Intolerance of Uncertainty Scale (IUS) measures individuals' tendency to find uncertain situations distressing, a construct linked directly to anxiety and worry. Since its publication in 1994 by Freeston et. al, the scale has been widely used in research due to its strong construct validity and reliability. To investigate potential generational changes, we conducted a cross-temporal meta-analysis of studies using the 27-item IUS with undergraduate samples in the United States and Canada. Building on Carleton et al. (2016), who reviewed publications from 1994 to 2014, we extended the analysis to include studies published between 2014 and 2024. From over 1,800 papers screened, 52 met eligibility criteria. Results indicate that mean IUS scores among North American undergraduates have continued to increase over the past decade. These findings suggest a rising intolerance of uncertainty in this population. While we posit some reasons this might be the case, such as a rise in mobile phone penetration, further research is needed to clarify the specific factors contributing to this trend.

Valeria Alanis BC'26, Computer Science, Daniella Cardenas SEAS'26, Computer Science, Mishael Khan BC'25, Mathematics

Faculty Mentor(s) or Supervisor(s): Lucy Simko
Title: Understanding Today's Immigrants' Digital Security and Privacy Experiences

Abstract: The U.S. government administration has issued a series of restrictive immigration policies since January 2025. According to the United States' official ICE website, during the first 100 days of President Trump's second term (January 20-April 20, 2025), 66,463 immigrants were arrested and 65,682 were deported. Three months later, President Trump's reconciliation bill allocated approximately $170 billion to immigration and border enforcement. This study examines how immigrants in the U.S. may be adapting their digital privacy and security practices in response to these political changes. Through in-person flyering, research platform recruitment, and personal networks, we conducted semi-structured, hour-long interviews (n=11) with recent immigrants of diverse origin and legal status. To ensure the safety of our participants, we obtained informed consent, redacted any identifying information from interview transcripts, and stored all research data locally. Our analysis reveals that participants exhibit widespread institutional distrust aimed at the government, social media companies, and data brokers; demonstrate heightened levels of hyper-vigilance both on-and-off line; and employ extensive self-censorship ranging from limiting their conversations online to fully opting out of social media platforms in the effort to protect themselves and their communities. These findings highlight how current immigration policies erode the digital and physical autonomy of many immigrants, underscoring the need for privacy-preserving technologies and data policy reforms. Through a paper synthesizing our findings and recommendations, we aim to mitigate the disproportionate burden of security and privacy placed on immigrants, ultimately fostering safer digital spaces for marginalized communities.

Una Aleksic GS'26, Psychology

Faculty Mentor(s) or Supervisor(s): Usha Barahmand
Title: Psychosis Proneness in the Aftermath of Trauma: Cognitive, Affective, and Personality Pathways

Abstract: Traumatic experiences are a known risk factor for developing psychosis-related symptoms, such as paranoia, hallucinations, and disorganized thinking. However, the psychological mechanisms that explain this connection are still being investigated. This study examined whether dissociation, trauma-related cognitions, and experiential avoidance help explain how trauma exposure is linked to psychosis proneness in non-clinical populations. A sample of 289 adults completed validated self-report measures assessing symptoms of trauma, psychosis, dissociation, trauma-related cognitions, and experiential avoidance. A serial mediation model was used to test whether these variables explain the pathway from symptoms of trauma to psychosis proneness.
Results showed that the total effect of trauma symptoms on psychosis proneness was significant. However, this effect became non-significant when mediating variables were included, indicating full mediation. Three key pathways emerged: (1) Traumatic symptoms predicted psychosis proneness through increased dissociation; (2) Traumatic symptoms led to greater experiential avoidance, which in turn increased psychosis risk; and (3) Traumatic symptoms led to more negative trauma-related cognitions, which increased dissociation and ultimately predicted psychosis proneness.

These findings highlight dissociation as a central mechanism in the trauma-to-psychosis pathway and suggest that avoidant coping and trauma-related beliefs may contribute to this risk. Targeting dissociative experiences, avoidance, and negative cognitions in trauma-exposed individuals may help reduce vulnerability to psychosis.

Teresa Alves Sabin CC’26, Astrophysics

Faculty Mentor(s) or Supervisor(s): Frederick Paerels
Title: Reanalyzing Atomic Absorption Features in the High-Resolution X-ray Spectrum of the Neutron Star in EXO 0748-676

Abstract: The X-ray spectrum of the neutron star in the binary EXO 0748 − 676, discovered in 1986, obtained with NASA’s Chandra X-ray Observatory, was reanalyzed. This is, along with the X-ray spectrum of the star in Puppis A, one of only two spectra of such quality ever obtained (single neutron stars are faint, and for accreting neutron stars in binaries, one can only use a few tenths of a percent of the observation, when the star is bursting). The spectrum clearly exhibits a bump at photon energies corresponding to the K spectrum of highly ionized iron, which has remained unexplained; it appears blurred. The star spins at 550 Hz, so the blurring is expected; it is associated with the Doppler effect. The objective was to simulate the spectrum that should be observed from a hot neutron star close to blowing up the atmosphere (in this case, ∼ 10^7 K and above) and to apply the blurring due to rapid rotation of the star and then compare it to the spectrum of EXO 0748 − 676, using three models: a Blackbody Model, a Doppler Smeared Spectrum Model (DSSM), and the Model Atmospheres. The Iron XXVI was present in all models, verifying its presence in the neutron star's atmosphere. The best model was the DSSM, which will serve for future models of X-Ray bursts of neutron star.

Sebastian Anderson SEAS’27, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Clark Hung
Title: Mechanical Loading Modulates the Hemarthrosis Response of Cultured Human ACL Fibroblasts

Abstract: The anterior cruciate ligament (ACL) is exposed to hemarthrosis, or intra-articular bleeding, following joint trauma. Red blood cells (RBCs) in the joint degrade and release hemoglobin and heme, which stimulate inflammation, oxidative stress, and iron deposition in surrounding tissues. These degradation products increase nitric oxide (NO) production and upregulate inflammatory and catabolic gene expression in fibroblasts found in the joint and synovial cells. While these effects have been studied in static systems, the role of mechanical loading in shaping responses to blood exposure remains unclear. Cyclic strain is important in musculoskeletal health, with low levels promoting repair and high levels triggering cell inflammation. This study employs a two-dimensional co-culture model to evaluate how applied strain alters the response of human ACL fibroblasts (hACLFs) following RBC exposure. Fibroblasts were co-cultured with RBCs, and subjected to either low or injurious cyclic strain. Cell morphology, nitrite levels, and gene expression were assessed. Low strain moderately increased cell density, while RBC exposure reduced cell viability. In RBC-free conditions, nitrite levels increased with strain, and following RBC exposure, sub-physiologic strain elevated nitrite concentration while injurious strain led to a significant reduction. Injuriously loaded hACLFs demonstrated a significant upregulation of all examined gene markers. However, when combined with RBC exposure, injurious loading resulted in a marked reduction in expression across all relevant markers. These findings support our hypothesis that mechanical loading modulates fibroblast responses to blood exposure. Understanding these interactions may help guide therapeutic strategies to limit hemarthrosis-induced damage and improve ligament healing.

Notavious Andino-Galarza CC’26, Cognitive Science, Hanna Cohen CC’26, Psychology, Shawna Lane CC’27, Political Science-Statistics, Tina Nguyen CC’27, Economics-Political Science

Faculty Mentor(s) or Supervisor(s): Sarah Ashcroft Jones
Title: Testing the Effectiveness of Loss vs. Gain Frames in Climate Change Messaging: A Multi-Country Study

Abstract: This case study aims to code climate messaging into two primary themes: loss-frame and gain-frame. Within this study, a loss frame is defined as the “negative consequences of not undertaking a particular behaviour", whereas a gain frame is defined as the “positive consequences of undertaking a particular behaviour”(Spence & Pidgeon, 2010). A deductive semantic approach was used to thematically explore political discussion. Beyond this, speeches given at the 29th United Nations Climate Change Conference (COP29) were used as the focus of analysis to ensure a standardised dataset. The result was denoted in a policy table, leaving each country's address to fall within either a Loss-Frame, Gain-Frame, or neutral stance in terms of climate

messaging. A broader study based upon the same framing was used to contextualize this. This case study, in particular, found that all nations relied on either a Gain-Frame or Neutral stance to relay their messaging, which could be further applied when constructing large-scale climate policy communication.

Eduardo Arteaga CC'26, Chemistry, Neuroscience

Faculty Mentor(s) or Supervisor(s): Paul Garcia
Title: Evaluating the Therapeutic Potential and Sex-Specific Effects of Ketamine, Ketamyne, and Noribogaine on Anhedonia in Naive and Chronic Depressed Mice

Abstract: While SSRIs are an invaluable treatment for depression, the onset for SSRIs to exhibit their anti-depressive effects, which can be anywhere from 2-3 weeks, is a potential barrier to depressed patients who may need faster acting solutions. Recently, psychedelics have emerged to fit this gap. At subanesthetic doses, the NMDA receptor antagonist ketamine exhibits analgesic, anxiolytic, and antidepressant properties, making it a promising treatment for mood disorders. In this study, we explore the therapeutic potential of a novel ketamine derivative, ketamyne (2-(but-2-yn-1-ylamino)-2-(2-chlorophenyl) cyclohexan-1-one) for its antidepressant efficacy. Additionally, noribogaine, the active metabolite of ibogaine, is investigated for its antidepressant effects, possibly through modulation of SERT, VMAT2, and NMDA (also as an antagonist) receptor systems. Prevalence of major depressive episodes was higher among adult females (10.3%) compared to males (6.2%). Because sex differences in depression have been confirmed in prior research studies, both male and female mice were included in our experiments to assess for sex-specific responses to ketamyne, ketamine, and noribogaine. To better understand the antidepressant effects of ketamyne, this study compares its behavioral outcomes with those of ketamine and noribogaine across two experimental paradigms: (1) acute behavioral screening and (2) a chronic stress-induced model of depression. In both of these paradigms mice were assessed for behavioral despair by immobility time in the tail suspension test, hyperactive effects by locomotion in the open field test, spatial working memory and exploratory behavior in the Y-maze novel arm test. Based on the results from previous literature, a successful treatment is hypothesized to demonstrate a reduction of immobility time, a locomotion comparable to pre-treatment, and increased memory.

Olivia Avila CC'27, Computer Science

Faculty Mentor(s) or Supervisor(s): Zhu-Tian Chen
Title: Investigating AI Reliance in a Mobile vs. AR Environment

Abstract: As Augmented Reality (AR) headsets become more integrated in everyday life through advancements and recent releases by companies like Meta and Google, understanding how users make decisions in AR compared to mobile interfaces is worth investigating. Therefore, this project seeks to discover and understand what unique factors of AR influence user decision-making with AI-generated suggestions, with implications for future AR decision support systems. Building on previous research in human-AI collaboration, 9 decision making tasks were designed to measure AR's influence on AI usage vs. a mobile's influence. An experiment was conducted in which there was a comparison of the outcome of each task done first with a mobile phone interface, to the outcome of the same tasks done again by the same participant but with an AR interface highlighting AI's suggestion.

Lucas Azenha CC'27, Mathematics, Luiz Backes GS'27, Mathematics, Pranav Suresh CC'27, Mathematics

Faculty Mentor(s) or Supervisor(s): George Dragomir
Title: From Nests to Networks: Modeling Supercolony Structure in Social Weavers

Abstract: Animal societies frequently display multilevel cooperation, but understanding how large-scale coordination arises from individual interactions remains a challenge. In this study, we analyze more than 6 million RFID detections from a population of cooperatively breeding birds over five years to identify persistent dyadic interactions. We construct dynamic social networks that capture long-term co-presence across individuals, colonies, and spatial plots. Using graph-theoretic and metadata-based methods, we identify 108 supercolonies, emergent social structures defined by recurring patterns of persistent intercolony cooperation. In particular, male-female dyads disproportionately drive long-range connectivity, whereas female-female ties stabilize within-colony cohesion. These layered structures are robust and replicable, reflecting forms such as hubs and chains that support spatially distributed social organization. Our approach offers a generalizable framework for studying decentralized cooperation in dynamic ecological networks.

Sage Bailey CC'28, Chemical Physics

Faculty Mentor(s) or Supervisor(s): Milan Delor
Title: BPVE in TMD: How to improve solar panel efficiency

Abstract: Understanding how crystal symmetry affects light–matter interactions is key to designing next-generation solar energy materials. The bulk photovoltaic effect (BPVE), which converts optical energy into direct current in materials with broken inversion symmetry, enables photovoltages beyond the band gap. Transition metal dichalcogenides (TMDs) are a promising platform for exploring this phenomenon. For example, 3R-MoS_2 exhibits BPVE, while 2H-MoS_2, which has the same chemical composition but different symmetry, does not. The 2H phase is centrosymmetric, whereas the 3R phase lacks inversion symmetry, allowing directional charge transport. To enable a direct comparison, we mechanically exfoliated both materials to four-layer flakes. Visualizing how BPVE depends on crystal structure has remained limited due to the challenges of nanoscale imaging. Using stroboSCAT, an imaging technique developed in the Delor Lab, we track exciton and free carrier transport with high spatial resolution. Complementary transient reflectance measurements capture energy shifts over time. Comparison of stroboSCAT data from thin flakes of 2H-MoS_2 and 3R-MoS_2 reveals distinct image contrast linked to crystal symmetry. Transient reflectance further shows differences in energy redistribution between the two phases. Together, these techniques provide new insight into how inversion symmetry governs the bulk photovoltaic effect and highlight opportunities for designing more efficient solar energy materials.

Thilina Balasooriya CC'26, Computer Science

Faculty Mentor(s) or Supervisor(s): Shinjae Yoo
Title: Mamba as a Backbone for Generalizable Implicit Neural Representation for Extreme Scale Domains

Abstract: Implicit neural representations (INR) are neural networks that can represent the underlying continuous function behind discrete data (such as images, spatiotemporal scientific data, etc.). To generalize the creation of INRs, Generalizable INR (GINR) has been researched to generate INRs from latent representations of data. Existing methods like hypernetworks or cross-attention/transformer based GINR fall short due to their inability to scale to extreme input lengths. To this end, we study the potential of Mamba, a novel deep learning architecture, which scales linearly with input size (unlike transformers, which scale quadratically) as a backbone for GINR models on scientific datasets that present challenges such as extremely large input size, unpredictable sparsity patterns, and variable data collection frequency. We find that replacing the Transformer hypernetworks in state-of-the-art GINR works with Mamba backbones lead to increased peak signal-to-noise ratio (PSNR) in image reconstruction tasks and better performance in super resolution. We also study the use of equidistantly interleaved learnable tokens in sequences fed to Mamba models using t-SNE and find that positional encodings enable the model to learn to distinguish between data tokens and learnable tokens.

Caroline Baldessin GS'26, Psychology

Faculty Mentor(s) or Supervisor(s): Carl Hart
Title: "Pink Cocaine" Panic: Media Sensationalism and the Death of Liam Payne

Abstract: This paper examines the sensationalized media coverage surrounding the death of British singer Liam Payne in October 2024, with a particular focus on the premature and inaccurate association of his death with the drug "pink cocaine." Using qualitative media analysis, the study compares official toxicology findings released by the Argentinian Prosecutor's Office with initial reports from mainstream media outlets, many of which relied on anonymous sources and speculative claims. Thematic coding of fifteen articles revealed a pattern of exaggerated reporting, often prioritizing audience engagement over factual accuracy. Despite official findings that listed only alcohol, cocaine, and sertraline, several outlets falsely cited methamphetamine, crack cocaine, benzodiazepines, and "pink cocaine" as causes of death. The analysis highlights how fear-based journalism exploits unfamiliar substances to manufacture public hysteria, resulting in reputational damage to both the deceased and those associated with them. This case study contributes to a broader critique of the media's role in shaping drug-related narratives, demonstrating how misinformation, commercial incentives, and audience biases reinforce a cycle of panic and distortion. The paper calls for more ethical journalistic practices and a societal shift toward consuming information with critical awareness and empathy.

Rithik Banerjee SEAS'27, Computer Science

Faculty Mentor(s) or Supervisor(s): Carlos Paz-Soldan
Title: Application of Single Stage Optimization to Generate "Banana Coil" Configurations For Upgrade on Columbia HBT Experiment

Abstract: This project explores a new configuration for a fusion energy device to an existing experiment at Columbia University. This project aims to optimize a set of "banana-shaped" coils into the Columbia High Beta Tokamak (HBT) experiment for magnetic confinement purposes. These coils are intended to reshape the magnetic field inside HBT to access new physics

properties, turning it into a hybrid device that behaves like a stellarator—a type of fusion device that uses complex magnets to confine plasma without needing a plasma current. The goal of this research is to create magnetic field configurations that improve plasma confinement while ensuring the coil design is physically realistic and can fit into the existing HBT setup. The project uses a computational tool called SIMSOPT to optimize both the plasma shape and the coil geometry at the same time, which is a relatively new method in this field. This technique avoids earlier multi-step methods by directly generating desired plasma equilibria that works best for magnetic confinement with the given coil configuration. Further, the optimization process involves an adaptive resolution strategy to helps ensure that results are converged and physically meaningful. The final designs meet important goals like target plasma volume, rotational transform, quasisymmetry, and engineering constraints, all while producing magnetic fields that are suitable for future experiments. This work demonstrates the potential for a short-term upgrade to HBT using modern optimization techniques.

Amanda Benneh CC'28, Biology, Public Health

Faculty Mentor(s) or Supervisor(s): Jennifer Small-Saunders
Title: Investigating the Role of the m1G9 tRNA Methyltransferase in P. Falciparum Resistance to Antimalarial Drugs

Abstract: Malaria, a mosquito-borne disease caused by the Plasmodium falciparum parasite, causes ~250 million cases and ~600,000 deaths worldwide. The production of antimalarials, such as first-line treatment Artemisinin Combination Therapy (ACT), has been instrumental in decreasing malaria cases. However, the emergence of parasite resistance to antimalarial drugs, including Artemisinin (ART), poses a significant threat to the elimination of this deadly disease. Mutations in Kelch-like protein (K13) have been identified as the primary driver of ART-resistance. However, recent work has also shown that transfer RNA (tRNA) modifications may also contribute to Pf resistance mechanisms. These chemical modifications are synthesized by specific methyltransferases. In settings of stress, reprogramming of individual tRNA modifications can change translational speed and fidelity and/or tRNA stabilization leading to 'just-in-time' translation of key stress response proteins. We hypothesized that alteration in m1G modifications would alter Pf stress responses. We used CRISPR/Cas9 gene editing to knock out the predicted m1G9 methyltransferase (Pf3D7_1119100), which catalyzes the addition of a methyl group to the N1 position of guanine at position 9 in tRNAs. We performed 72-hour in vitro drug susceptibility assays to determine the half-maximal inhibitory concentration (IC50) values for a set of antimalarial drugs. KO parasites had decreased susceptibility to the mitochondrial inhibitor, DSM-265 and Atovaquone, as compared to WT parasites. There was no change in susceptibility to other common antimalarials. Our data will expose the role of m1G9 modifications in Pf stress responses with the goal of identifying new targets for antimalarials to treat drug resistant malaria.

Uriel Benymon GS'27, Computer Science

Faculty Mentor(s) or Supervisor(s): Paul Blaer
Title: Exploring Improvements to B-Tree Index Structures for Database Optimization

Abstract: Information for student records, financial services, and even healthcare systems are all largely managed by databases and the data structures inside them. Data structures are programs computers use to efficiently manage and store data. They are fundamental for databases, which serve the same purpose but on larger scales. Databases use data structures called indexes, and one is called the B-Tree. Indexes perform operations including searching, inserting, and deleting data inside the columns and rows of databases. While efficient for generalized data management, pressure is placed on indexes when operations are executed at the same time (concurrently) by clients to maintain speed and performance. This pressure increases when handling data in large amounts, duplicates, and across worldwide connectivity. Concurrent operations in databases using B-Trees are the topic of this study. During the study, the database PostgreSQL and its B-Tree index were analyzed alongside its other indexes (Hash, BRIN, etc.) for comparisons. For analyses, a benchmarking environment was developed using the programming languages Java and SQL for baseline performance measurements of PostgreSQL's indexes across randomized and standardized data. This environment illuminated trade-offs for modern B-Tree models. Based on these findings, a modified B-Tree was tested alongside the native version in PostgreSQL under concurrent environments. Preliminary results showed performance trade-offs, including approximately 30% faster concurrent insertion speeds under modified B-Tree configurations, highlighting opportunities to optimize database speeds across varying computer models and index design choices.

Patricia Bessie CC'26, Political Science

Faculty Mentor(s) or Supervisor(s): Laura Neitzel
Title: Histories & Health Impacts of Hyper-Individualism in American Weight Discourse

Abstract: This research explores how the concept of "laziness" has been used by powerful systems to justify exploitation and maintain social inequalities, both historically and in the present day. It begins by examining colonial-era narratives, where colonized peoples were labeled as lazy to rationalize their subjugation, forced labor, and the imposition of European cultural values. Colonial powers used this label to create artificial hierarchies among groups, often dividing them based on perceived work ethic and usefulness to the colonial economy. These ideas were supported by Western thinkers and administrators who promoted paternalistic forms of governance, claiming colonized people were not mature enough for liberty.
The project then connects these historical narratives to contemporary American health discourse, particularly around obesity. In the modern context, the label of laziness is used to shift responsibility for poor health outcomes away from structural and economic conditions and onto individuals. Efforts to address public health issues, such as school lunch reforms, are often dismissed as government overreach, reflecting a deep cultural bias against collective solutions. By tracing the continuity of this "laziness" narrative from colonial times to present-day health rhetoric, this research shows how old ideas continue to shape modern policies and public attitudes. It calls for a reevaluation of how we understand responsibility, health, and inequality in order to better address systemic issues that are often hidden behind individual blame.

Maya Bhaskar CC'28, Biophysics

Faculty Mentor(s) or Supervisor(s): Erin Barnhart
Title: Mitochondrial Mislocalization and the Optomotor Response in Young Flies

Abstract: Deficits in mitochondrial dynamics across cell populations are linked to neurodegenerative diseases that may negatively impact behavior. However, it remains unclear if mitochondrial dysfunction within one cell type can affect behavior. In this work, researchers examined the effect of disrupting mitochondrial transport in one class of visual neurons in Drosophila melanogaster and measured the effect on visually motivated behavior. Firstly, the researchers were able to replicate a functional fly-on-ball assay that elicits and measures the optomotor response. Flies are naturally known to turn in the direction of a moving visual pattern—this response allows them to quickly reorient their visual understanding and is known as the "optomotor response." The researchers then demonstrate that the amplitude of the optomotor response depends on stimulus speed. They finally knocked down the mitochondrial transport protein Milton in Mi1 visual neurons and measured the effect on the fly optomotor response. They ultimately found that knocking down Milton does not impact the optomotor response to square wave grating stimuli for flies aged 1-3 days old and 7 days old. These results further verify the use of a fly-on-ball assay to measure optomotor behavior and act as a first step to a broader understanding of the role of mitochondrial distribution in fly behavior.

Alexander Boeckmann SEAS'28, Electrical Engineering

Faculty Mentor(s) or Supervisor(s): Jeffrey Levesque
Title: Predicting HBT-EP Plasma Mode Amplitude and Phase with High Speed Image Data

Abstract: This project focuses on stabilizing plasma in the HBT-EP tokamak, a device for studying nuclear fusion, by using advanced machine learning techniques. A high-speed camera records plasma movements in real time, and the data is analyzed by a convolutional neural network (CNN), a type of artificial intelligence model. The CNN predicts key plasma characteristics, such as mode amplitudes and phases, which are essential for maintaining stable plasma behavior. To make these predictions fast and practical, the CNN is implemented on a field-programmable gate array (FPGA), a specialized hardware that processes data with minimal delay, building on previous work from 2023 by Y. Wei on optical plasma tracking. Unlike earlier methods, this project employs a genetic algorithm, a method inspired by natural selection, to automatically optimize the CNN's structure and settings. This results in highly accurate predictions, with an error rate of only 3.33%, outperforming traditional manual adjustments. By improving plasma control, this work reduces the risk of disruptions in the tokamak. In the future, the team plans to test this model directly on the HBT-EP tokamak's FPGA system to further refine real-time plasma stabilization. This approach could pave the way for more reliable and efficient fusion energy research.

Savannah Botello CC'27, Chemical Physics

Faculty Mentor(s) or Supervisor(s): Anna Elizabeth Champ
Title: Dimensional Effects of Host Environments on Molecular Spin Qubit Performance

Abstract: Molecular spin qubits (MSQs) are emerging as highly tunable and chemically versatile candidates for quantum sensing applications. However, depositing MSQs onto solid-state platforms has been shown to disrupt their relaxation and coherence lifetimes - properties that make them useful as

sensors in the first place. To address this issue, cobaltocene (CoCp2) was intercalated as an MSQ into 2D van der Waals bulk single crystals to observe the effects of bi-layer capping on the electron spin as opposed to monolayer attachment. Preliminary results indicated that the electron environment of CoCp2 changes dramatically in all three coordinate directions. This is interesting because CoCp2 in its pure molecular state typically possesses an axial configuration, meaning that the electron cloud configuration is equal in only two coordinate directions. Therefore, a control study is required to systematically compare the properties of the purely molecular CoCp2 to that of the intercalated CoCp2 system. To accomplish this, CoCp2 was integrated into 3D hosts as the control group to make sure that the results seen in the 2D hosts are unique and real. The 3D hosts used as the control groups are ruthenocene (RuCp2), ferrocene (FeCp2), and nickelocene (NiCp2). The goal is to ensure that the 3D hosts do not vary the properties of the qubits and should reflect the anisotropic nature of cobaltocene.

Flavia Bottai SEAS'26, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Ryan J. Halter
Title: Optimization of an Imaging-Compatible Oral Retractor System for Image-Guided Transoral Robotic Surgery

Abstract: Transoral robotic surgery (TORS) is a minimally invasive approach to treat oral and oropharyngeal cancers, but its effectiveness is limited by metallic oral retractors that create artifacts in CT imaging, are unsafe for MRI, and are cumbersome to set up. The lack of an imaging-compatible retractor poses a major barrier to achieving intraoperative CT/MRI guidance, which could substantially improve surgical precision in locating and removing tumors and ultimately enhance patient outcomes.
This project aimed to redesign an oral retractor and suspension system to be fully imaging-compatible while remaining practical for use with the da Vinci robotic platform. Building on prior prototypes, the team addressed issues surgeons encountered in the operating room, including CT interference, limited adjustability, and difficulty accommodating different patient anatomies. Using SolidWorks, a new design was modeled, 3D printed, and iteratively refined through cadaver head testing with direct surgeon feedback. Final versions were manufactured using sterilizable resin, carbon fiber, and nylon composites to balance strength, durability, and clinical compatibility. Bench-top, cadaveric, and early patient studies showed that the polymer retractor enabled artifact-free CT and MRI imaging while maintaining functionality for robotic procedures. The system proved intuitive to set up, compatible with da Vinci platforms, and durable under surgical loads. Patient trials are now underway, marking the first clinical use of an imaging-compatible retractor for TORS. This innovation represents a critical step toward enabling intraoperative image-guided robotic surgery, with the potential to transform surgical navigation, improve outcomes, and enhance quality of life.

Alexandra Bradbury SEAS'26, Chemical Engineering

Faculty Mentor(s) or Supervisor(s): Oscar Nordness
Title: Investigating Cation Effects for Deep Eutectic Solvents (DES)-Catalyzed PET Depolymerization and Recycling

Abstract: Polyethylene Terephthalate (PET) polymer materials are broadly used in materials such as, clothing, packaging, and plastic storage containers. To mitigate the detrimental environmental and public health effects of plastic and microplastic pollution, new solutions are necessary for the recycling and upcycling of plastic waste. Currently, PET and other plastic wastes are primarily recycled mechanically through a series of processes including cutting, crushing, and melting resulting in material degradation over repeated use1. Alternatively, chemical recycling via the depolymerization of PET to the bis(2-hydroxyethyl) terephthalate (BHET) monomer offers a promising avenue towards closing the plastic loop and mitigating plastic and microplastic pollution. Recently, Deep Eutectic Solvents (DESs) have been demonstrated as a promising medium to catalyze PET depolymerization. These materials - which are a mixture of two or more components that form a eutectic mixture - offer several favorable properties including relatively low cost, high thermal and electrochemical stability, and low volatility. Furthermore, DESs offer high solubility for metal salts necessary for catalyzing the reaction in the absence of water. In this work, we focus on the application of type (I) DES materials comprised of metal chlorides and quaternary ammonium salts as catalysts for PET depolymerization. Specifically, we investigate the influence of a series of metal chlorides (MCln) for catalyzing PET depolymerization and characterize the depolymerization kinetics, reaction temperature, and the DES to PET mass ratios for batch depolymerization. This work provides important insights towards generating a sustainable and commercially viable process.

Jackson Bramlette CC'27, Climate System Science

Faculty Mentor(s) or Supervisor(s): Andre Santos
Title: Phone Magnetometer Performance Analysis: A Citizen Science Initiative

Abstract: Undocumented Orphan Wells (UOWs) are abandoned oil and gas wells that remain unregistered with any well databases. Over one million are spread throughout the United States. Magnetometers–instruments which detect local magnetic field strength–expedite identification by detecting UOWs' ferrous well casings. However, identification surveys are limited in scope. To upscale UOW identification, scientists have developed numerous phone magnetometer apps and deployed Citizen Science: an initiative in which the public performs UOW surveys. The purpose of this research is to summarize the results of an experiment assessing three phone magnetometer apps–PhysicsToolbox, CrowdMag, and MagMapper–for their capacity to facilitate Citizen Science. A sensitivity analysis was performed on the applications to assess their susceptibility to noise and drift. Subsequently, an experimental survey was performed at the Richmond Field Station, in which the apps' performances were compared with the G-864 Cesium Vapor Magnetometer. Each survey consisted of three routes within a gridded 30 square meter region centered by a ferrous metallic pipe. Contour heat maps of each survey were produced, and the phone and G-864 results were compared using a gridded interpolation and subtraction scheme. Standard statistical analyses were performed. All three apps successfully identified the same anomalous features as the G-864 Magnetometer. PhysicsToolbox most successfully identified the anomaly, with MagMapper performing similarly.

Lindsey Brown GS'26, Neuroscience and Behavior, Owen Puhl CC'28, Computer Science and Mathematics

Faculty Mentor(s) or Supervisor(s): Sarah Ashcroft-Jones
Title: Doing Global Research: Challenges and Recommendations based on a 26-country study

Abstract: Global problems demand global evidence. This project reports on the design and delivery of a cross-national climate communication study conducted across twenty-six countries and eighteen languages. The jGlobal team developed a standard protocol, translated and back-translated all materials, obtained ethics approval, and coordinated local recruitment through online, university, and social partners. This study used a randomized online survey to compare how two common message styles about climate change are received. Equally important, this study documented the practical challenges of doing research across borders and offered ways to address them.
Five lessons about global research stand out. First, shared measures and clear data quality rules are essential to make results comparable across countries. Second, careful translation, including back translation and local review, prevents minor wording shifts from altering meaning. Third, recruitment methods must fit local norms to reach diverse samples. Fourth, preregistration and transparent reporting build trust when samples and contexts vary. Fifth, behavior is more difficult to change than attitudes; therefore, studies should include observable actions whenever possible. Based on these lessons, the project recommends that future global studies invest early in translation workflows, create minimum data quality standards before launch, pilot locally, and pair intention measures with simple behavioral tasks. It also proposes a public codebook for classifying political climate speech and a shared repository of country-level notes to speed future collaborations. By focusing on process as well as outcomes, this work offers a practical template for rigorous global behavioral research.

Mara Bulzan GS'26, Human Rights, Political Science

Faculty Mentor(s) or Supervisor(s): Cristiana Grigore
Title: Staging the Deportations to Transnistria: Romania's Violent Performance of the Roma Holocaust

Abstract: Popular portrayals of Roma peoples (derogatorily referred to as "gypsies") reduce them to free-spirited seductresses, endowed with mystical powers but devoid of ethical principles. These narratives obscure the centuries of enslavement, persecution, and eugenic violence they have endured. This historical erasure is compounded by the recent rise of far-right political discourse in Eastern Europe, where electoral campaigns distort the history of the Roma Holocaust and rehabilitate authoritarian figures.
Using performance theory in political violence, this research project examines how Romania's deportation and extermination of Roma peoples in Transnistria functioned as a self-directed performance of state power. The findings show that Antonescu's regime pursued an ideologically driven campaign of dispossessive mass killings, operating independently from Nazi directives and rooted in top-down political decisions rather than mass public pressure or "ancient hatreds." Unlike Nazi models of systematic extermination, Romanian authorities adopted a distinctively chaotic and excessively violent approach. The deportations were not designed for efficient extermination but became a staged display of racialized state violence by removing Roma families from their homes, degrading them in forced labor camps, and using their suffering to assert control and instill fear among both victims and bystanders. Grounded in archival research and oral histories of survivors, and supported by Columbia University's Roma Peoples Project under Cristiana Grigore, this study underscores the urgency of confronting Romania's role in the Roma Holocaust. Examining such cases of

dispossessive mass killings is essential to resisting historical revisionism and the ongoing weaponization of Roma identities for political purposes today.

José Caballero CC'26, Cognitive Science

Faculty Mentor(s) or Supervisor(s): Christopher T. Wimer, Danielle Wilson
Title: The Impact of Health and Income Benefits by Age and Race: Evidence from the Health Inclusive Poverty Measure

Abstract: Poverty is tied to notions of wellbeing and human need. Poverty measures therefore define who is in poverty and quantify how many people are in poverty. These measures compare resources with needs and rest on normative assumptions about what constitutes an adequate level of wellbeing. A central challenge is that "need" can be defined in different ways, as in the Supplemental Poverty Measure (SPM) and the more recent Health-Inclusive Poverty Measure (HIPM). The SPM defines need based on basic living costs such as food, clothing, shelter, and utilities, whereas the HIPM extends this definition to include medical needs and the adequacy of insurance coverage. Using the Current Population Survey Annual Social and Economic Supplement (CPS ASEC), I compare poverty rates under both measures for the United States overall and across demographic subgroups. I then implement counterfactual analyses to assess how major safety net programs reduce poverty under each measure and to compare these effects across measures. I show that alternative definitions of need change both the level and composition of measured poverty and the estimated effects of safety net programs, including those tied to insurance coverage. These differences affect how poverty is measured, how policies are characterized, and how recent changes to programs such as Medicare and Medicaid are evaluated.

Gabriella Calabia CC'26, Cognitive Science

Faculty Mentor(s) or Supervisor(s): Gabriella Vigliocco
Title: Words in the World

Abstract: Language is paramount to our communication with others and understanding of the world. The central question guiding our research is how children develop meaning of novel words. In this study, we focused on examining how young children begin to form associations between new vocabulary and their physical object representations. To do so we observed 40 caregiver-child dyads in their homes—aiming to maintain as naturalistic an environment as possible. During recorded research sessions, children aged three to four years old were were introduced to new words paired with corresponding toy object. Our aim was to examine how children engaged with these objects during spontaneous child-caregiver interactions. Importantly, we did not structure or direct the learning process. While data analysis is still ongoing, this research contributes to our understanding of early word learning in real-world contexts and the critical value of prioritizing ecologically valid environments. This research also has implications in both designing educational curricula and the role of caregivers in supporting language acquisition.

Daffny Cardoso SEAS'28, Mechanical Engineering

Faculty Mentor(s) or Supervisor(s): Kristin M. Myers
Title: AI-Based Image Cropping for Cervical Image Analysis in Preterm Birth Studies

Abstract: Preterm birth (PTB) affects 1 in 10 pregnancies in the United States and is the leading cause of infant mortality, yet its underlying causes are not fully understood. To understand PTB, it is important to analyze how changes in the makeup of the cervix alter its function. To characterize cervical function, the lab performs tension tests on a universal material testing machine that collects force, displacement, and time data to measure tissue response. The lab focuses on cervixes of mice with altered proteins and enzymes, such as the Mannose Receptor C-type 2 (MRC2), which can alter cervical function in pregnancy. During experiments, images are collected from the front and side angles of the tissue and then post-processed by a sequence of scripts in MATLAB and Python that crop the image, identify the boundaries of the cervix via segmentation, and measure its dimensions. A key challenge in this process has been to manually crop each experimental image, as each experiment has a minimum of 500 images captured. To streamline this process, this project developed a new method to process images: an AI-based image cropping code in Python trained on manually cropped images of wild-type and MRC2-deficient mouse cervix. The model has been able to accurately and consistently identify cervical regions from both the front and side angles. This novel code greatly increases computational efficiency in the testing protocol and reduces the time required to move into subsequent analysis, ultimately allowing the Myers Lab to better study the biomechanics of the cervix.

Seth Carmouche CC'26, Philosophy

Faculty Mentor(s) or Supervisor(s): Mark Lilla
Title: The Politics of Voodoo in the American South

Abstract: In the nineteenth and early twentieth centuries of New Orleans, it would not be uncommon for an individual down on their luck to secure the services of a Voodoo doctor. Part ritual and part religion, Voodoo offered the supplicant power over the unknown and an ability to influence events outside their control by exhorting the spirits. Voodoo had its apogee in the mid-nineteenth century, before state, city, and religious officials began the systematic dismantlement of the religion, largely employing racialized rhetoric. Utilizing newspapers, legal records, and interviews, this essay argues that Voodoo was targeted and proscribed by officials because it was increasingly perceived as an African religion, and in the context of Jim Crow, it represented a threat to white supremacy.

Ana Castro GS'27, Neuroscience

Faculty Mentor(s) or Supervisor(s): Michal Laniado Schwartzman
Title: Gpr75 Deletion in Adipocytes Protects from Diet Induced Obesity: Changes in Glucose Homeostasis and Inflammatory Responses

Abstract: Objective: Loss of function G-protein coupled receptor 75 (GPR75) variants in humans are associated with leanness and Gpr75 null mice are protected from diet-induced obesity (DIO). However, the mechanisms underlying this protection are largely unknown. Here, we investigated the contribution of adipocyte derived Gpr75 to DIO. Methods: Adipocyte-specific Gpr75 knockout (KO) male and female mice and their wild type (WT) littermates were placed on a high fat diet (HFD) for 14 weeks. Metabolic parameters including body weight, energy intake and expenditure, activity and glucose metabolism were monitored before and after diet feeding. Results: While WT mice obtained a diabetogenic phenotype on HFD, the KO counterparts were protected. This protection showed sexual dimorphism. Female KO mice displayed fifity percent decrease in weight gain and adiposity compared to WT, whereas male KO gained weight similar to WT mice. Interestingly, both male and female KO mice exhibited improved glucose handling compared to WT, which was correlated to decreased adiposity and adipose tissue inflammation and increased insulin sensitivity in skeletal muscle. Importantly, no differences in food intake were observed; however, KO mice showed increased activity and energy expenditure, regardless of sex. Conclusion: Taken together, these studies show that GPR75 deletion solely within adipocytes is sufficient to protect against DIO and suggests that peripheral factors such as adipokines are the driving force in preventing the metabolic complications of HFD feeding.

Gabriel Caumartin GS'26, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Filip Swirski
Title: Generating a brain-wide atlas of neuronal activity during myocardial infarction recovery

Abstract: Myocardial infarctions (MI), commonly referred to as "heart attacks," are leading global cause of mortality. For the over 800,000 Americans who experience an MI each year, the existing treatment options are good but still limited, especially regarding the recovery of the damaged parts of the heart. With a vision towards possible future therapeutics, the role of the brain in post-MI healing and recovery has recently been increasingly appreciated. So far, identifying which brain regions sense and respond to an MI has been challenging due to limitations in the available techniques. In light of this, we optimized a fast and reliable method to map brain-wide neuronal activation during MI healing by pairing a state-of-the-art tissue-clearing method with activity-dependent genetic labeling of neurons in a transgenic mouse model (TRAP2). Our optimized clearing method produced clear, intact brains, enabling rapid imaging of the entire brain with high resolution (~4μm). In mice with MI, we can catalog and quantify activated neurons throughout the brain at any timepoints following the MI. This allows us to probe which regions are differentially activated in MI compared to a control animal. We can additionally characterize a connectome of how the brain is connected to the heart by implementing our brain-wide imaging protocol to poly-synaptic retrograde viral tracing (PRV) from both cardiac ventricles. These findings provide insights on the link between the brain's activation after MI during the recovery phase and its structural capacity to directly regulate cardiac function.

Alex Chen CC'28, Biochemistry

Faculty Mentor(s) or Supervisor(s): Christine Chio
Title: Investigating Mechanisms of Labile Iron Pool Expansion During Adipose Browning

Abstract: Cancer-induced cachexia is associated with a severe reduction in body mass and affects 80% of individuals with pancreatic cancer, worsening their prognoses and reducing their quality of life. In these patients, adipose tissue undergoes metabolic reprogramming that causes fat atrophy in a process known as browning, which is regulated by the beta-3 adrenergic signaling pathway. Because fat loss precedes muscle loss in patients with cachexia, identifying the mechanisms that govern adipose tissue browning can be essential for developing diagnostic tools and therapeutics. Previous studies have pointed to iron regulation as being a key player in this metabolic

shift because iron accumulation can promote browning while depletion hinders it. Here, changes in adipose tissue upon browning are evaluated. Using T2* MRI to measure local iron levels, mice with pancreatic cancer-induced cachexia display elevated iron levels within subcutaneous white adipose tissue and reduced fat mass. The differentiation of adipocytes leads to an early spike in intracellular iron levels, indicating that free iron ions within the cell may be a contributor to this process. Interestingly, isoproterenol—an inducer of adipocyte browning—causes an expansion of the labile iron pool. Future research will investigate how iron regulation is altered upon beta-3 adrenergic signaling and whether impairment of labile iron pool expansion impacts adipocyte thermogenesis. Taken together, these results suggest that adipocyte browning in vitro and in vivo result in iron accumulation, providing more insight on how changes in adipose tissue contribute to cachexia in cancer patients.

Audrea Chen CC’28, Data Science, Political Science

Faculty Mentor(s) or Supervisor(s): Nicholas Bartlett
Title: Reframing Fuzhounese American Experiences: Migration, Inequality, and Community Resilience

Abstract: This research examines how economic struggle, irregular migration, and reductive portrayals have shaped the experiences of Fuzhounese Americans in New York City. Unlike Cantonese immigrants, who have gradually moved into the middle class, many Fuzhounese remain socioeconomically marginalized, often confined to low-wage service work and stigmatized through stereotypes of takeout restaurants, nail salons, and construction labor. Their stories, however, reveal both resilience and cultural preservation, qualities that remain underrepresented in academic scholarship. To recover and reframe these narratives, I conducted a review of current literature on the Fuzhounese diaspora, which revealed the persistence of narratives linking the community to criminality and illegality. Building on this foundation, I conducted interviews with Fuzhounese organizations in New York City, such as the Fuzhounese Sisters, and with professors who have worked extensively with the community. These conversations inspired a new direction: creating media, including a photography project, to reframe public perceptions of the Fuzhounese. Particular attention was given to the ethnic enclaves in Manhattan’s Chinatown near East Broadway and in Brooklyn’s Sunset Park, visually highlighting the economic patterns of Fuzhounese immigration. By situating the Fuzhounese within broader debates on Chinese American identity and urban inequity, this research challenges dominant depictions of illegality that have long dispossessed the community. It argues instead for a more nuanced account of Fuzhounese resilience, tracing how cycles of marginalization have generated alternative economies, cultural practices, and forms of belonging. In reframing their history, this project seeks to amplify an understudied community and contribute to the ongoing redefinition of the Chinese American experience.

Cara Chen CC’28, Economics, Linguistics

Faculty Mentor(s) or Supervisor(s): William Foley
Title: Improving Adult English Education in Underserved Communities in New York

Abstract: Around 30% of New Yorkers speak a language other than English at home; in New York, around 2.5 million people have limited English proficiency. In schools, this is addressed through ESL education programs; however, there are limited English education resources for adult learners. Many programs are English-only, which can be hard for adult learners with no previous exposure to English. Most non-English-only programs are oriented towards Spanish speakers, leaving out a large portion of adult learners from other language backgrounds. Furthermore, most research on language acquisition in academia focuses on childhood language acquisition. This project aims to compile the most effective methods for adult language education—many of which are applied to adult learners in university setting, but limited to English speakers learning foreign languages—and create a pedagogical program that could be implemented in the community. After a literature review was conducted, the findings were applied to create a lightweight series of English-Haitian Creole bilingual teaching materials that focused on grammatical fact comparison, useful vocabulary for everyday scenarios, and predicting common mistakes in the course of language acquisition due to the differences in language structure between the two languages. In the future, these pedagogical materials can be reproduced cheaply in mass quantities, allowing volunteers to better create access to English education for the adult communities here in New York and elsewhere.

Mark Chen SEAS’26, Computer Science, Hao Cui CC’26, Computer Science, Mathematics, Jonah Stockwell CC’27, Computer Science, Mathematics

Faculty Mentor(s) or Supervisor(s): Xi Chen
Title: (Almost) Settling the Complexity of Adaptive Monotonicity Testing of Boolean Functions

Abstract: The field of property testing extends past theory to profound practical implications — it studies the question deducing a "property" of a function by only looking at a very small fraction of its input/output pairs, allowing one to extract global information from a small amount of local samples. This field has applications ranging from the foundational machine learning and artificial intelligence to economics and financial modeling. The most standard, fundamental model is testing properties for functions on binary inputs (Boolean functions) where the tester can adapt with each sample and is allowed marginal error. Testing whether a function is monotone has been an important unsolved problem for 20 years; so much so that it has appeared in many textbooks and surveys. The final frontier of monotonicity testing has been either guaranteeing the optimality of the best-known testing algorithm, or finding a better algorithm. The last known improvement was published nearly nine years ago at one of the top conferences in theoretical computer science, the Symposium on the Theory of Computing (STOC), where some of the most prestigious prizes in computer science (the Knuth and Godel prizes) are given. Our result nearly closes the problem, showing no algorithm can perform better than the best-known algorithm, up to an arbitrarily small constant factor. We achieve this by breaking the barrier blocking generalizing the earlier "Talagrand" construction. Moreover, we close the gap in "relative-error monotonicity testing," a related model of recent interest.

Valerie Chiege CC'28, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Dr Shannon Gourley
Title: Mimicking and rescuing isolation-induced inflexibility via chemogenetic modulation of the vHC

Abstract: Background: Flexible behavior is defined as the ability for organisms to deviate from established behaviors by durably encoding new information and using newly formed memories to guide future choices. Chemogenetic tools, such as DREADDs, can be used to modulate the neural circuits involved with the formation of flexible behaviors. Here, we tested whether ventral hippocampus (vHC) projections to the ventrolateral orbitofrontal cortex (VLO) contribute to adolescent isolation-induced deficits in flexible behavior. Methods: C57BL/6 mice were randomly assigned to single or group housing during adolescence. In adulthood, single-housed mice were reintegrated into groups such that cages contained both previously isolated and group-housed mice. Chemogenetic strategies were used to investigate the role of excitatory neurons in the vHC in flexible behavior. To quantify behavioral flexibility mice were trained to generate two distinct responses for food, then one response ceased to be reinforced. Immunohistochemistry was used to quantify cFos levels in the vHC. Results: Social isolation impairs flexible behavior and is associated with increased cFos levels in the vHC. Chemogenetically stimulating vHC-VLO projections mimics isolation-induced inflexible behavior, which is rescued by chemogenetic inhibition of these neurons. cFos levels are increased in mice expressing Gq-DREADDs. Conclusion: Chemogenetic stimulation changed neuronal activity, as measured through cFos, as expected.

Austin Choi CC'27, Biology

Faculty Mentor(s) or Supervisor(s): Sandra Ryeom
Title: Adjuvant Versus Neoadjuvant Chemoimmunotherapy for Esophageal Squamous Cell Carcinoma

Abstract: Esophageal cancer is the seventh leading cause of cancer death, with over 500,000 deaths worldwide in 2022. Esophageal squamous cell carcinoma (ESCC) is the most common form of esophageal cancer and is a highly deadly cancer with limited therapeutic options. Immune checkpoint inhibitors have emerged as a breakthrough treatment by enhancing the immune system's ability to target and attack cancerous cells. However, optimal treatment timing still remains unclear. This study aims to evaluate the efficacy of administering immune checkpoint inhibitors alongside chemotherapy before surgery (neoadjuvant) versus after surgery (adjuvant) in treating mice with ESCC. A mouse ESCC cell line was injected into the flank of mice to establish tumors. Western blot analysis was used to confirm that the ESCC cell line had the right features for testing immunotherapy. Two pilot studies were conducted, demonstrating that approximately two million ESCC cells are required for tumor formation without regression and that different injection sites result in varying rates of tumor formation.
To investigate the efficacy of neoadjuvant versus adjuvant treatment, two cohorts of five mice will be treated with chemoimmunotherapy either before or after tumor resection. The chemoimmunotherapy regimen consists of a combination of chemotherapy and two immune checkpoint inhibitors: anti-PD-1 and anti-CTLA-4. The outcomes of this experiment will provide insights into the effects of therapy timing on tumor response and progression. Given the recent clinical shift toward testing neoadjuvant immunotherapy in ESCC, this work aims to inform treatment timing strategies by directly comparing the efficacy of neoadjuvant and adjuvant therapy.

Daniel Choi CC'26, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Lynn Yap
Title: Understanding false olfactory percepts in mouse piriform cortex

Abstract: Humans make sense of the world by making multi-modal associations within a vast network of sensory stimuli. Central to this process is constructing perception through internal models shaped by prior experience and expectation. While such models help resolve ambiguity, they may also generate false percepts in the absence of stimuli, as in hallucinations. However, little is known about the neural mechanisms of these processes. Implicit learning paradigms have shown that, after a tone–odor pairing is learned, the tone alone is sufficient to elicit an odor response in the mouse primary olfactory cortex. However, whether such neural responses reflect false odor percepts is unclear. Here, the mice were trained on a freely-moving auditory-odor association task to report whether they received an odor stimulus after the tone. Task-proficient mice falsely reported odor presentation on 14.2% and 11% of trials across two tone-odor pairings, suggesting that the tone elicited an odor percept in these false alarms. Neural probes were chronically implanted into the anterior piriform cortex of mice to record neural activity during the behavioral task. The recordings revealed neurons that responded to both odor delivery and false alarm trials when no odor was presented. Support vector machine analysis revealed that mice may lower their odor detection threshold during learning, which could have contributed to the false alarm rate by increasing sensitivity to weak piriform representations elicited by tone-evoked top-down pathways. Future work will focus on characterizing the neural circuitry by which these false percepts are generated.

Sofia Choudhri CC’28, Environmental Chemistry

Faculty Mentor(s) or Supervisor(s): Ann Sullivan Ojeda
Title: The Influence of Septic Systems On Streambed Groundwater Quality

Abstract: Over 40% of Alabama (AL) residents rely on Onsite Wastewater Treatment Systems (OWTS) to manage household wastewater. OWTS, most commonly known as septic systems, are used to treat wastewater when centralized treatment is unavailable. High densities of OWTS can increase the volume of septage beyond the soil’s capacity to purify, causing OWTS to fail and untreated effluent to contaminate groundwater. The EPA predicts that up to 70% of national OWTS are failing. However, the extent to which OWTS failure impacts surface water quality is not well understood. This study aimed to answer the question: Does OWTS density influence baseflow groundwater quality in nearby headwater streams in coastal Alabama? Streambed groundwater from 31 sites was collected using a temporary drive-point piezometer in Mobile and Baldwin County, AL. In-situ water quality parameters were measured, and samples were analyzed for both microbial source tracers (total coliforms, E. coli, HF183) and chemical source tracers (Na/K ratios,, acesulfame-K, sucralose, and nitrate). We used generalized linear models to explore the relationship between the tracers and OWTS density calculated for 4 buffer sizes around each sample site. We found that nitrate was positively correlated with OWTS density ($p < 0.05$) for 250m buffers, yet the results were not significant at other buffer sizes. Results from this pilot study will be used to support future research in coastal AL and ultimately inform watershed management plans to reduce environmental impacts from OWTS.

Alexandra Cochon SEAS’26, Biomedical Engineering, Nastexo Nur CC’28, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Santiago Correa
Title: Engineering Multicomponent, Biomimetic Hydrogels for Immune Cell Modulation

Abstract: A major challenge in cancer treatment is the development of targeted therapies that minimize off-target effects. Hydrogels have emerged as promising biomaterials because they can mimic the extracellular matrix and modulate the immune system within the tumor microenvironment. However, the influence of biopolymer composition, protein cargo, and crosslinking strategies on hydrogel properties—and their subsequent role in immune modulation—remains poorly understood. This work addresses that gap by systematically investigating key design parameters. Hyaluronic acid, a well-characterized hydrogel backbone, was chemically modified to examine how polymer length and crosslinking density affect gel mechanics. These modifications demonstrated that hydrogel density can be fine-tuned by altering polymer structure. Programmable release was then explored by encapsulating protein cargo within nanocages expressed in E. coli, with yield and purity assessed by BCA assays and SDS-PAGE. Finally, lymphocytes—including Natural Killer (NK) cells and Jurkat T cells—were metabolically labeled with sugars and conjugated to fluorescent markers. Fluorescence microscopy and flow cytometry revealed that NK cells exhibited stronger labeling and slightly higher cytotoxicity compared to Jurkat cells. Collectively, these findings support the development of modular hydrogels with tunable mechanical and biochemical properties. Future studies will integrate surface-labeled immune cells within hydrogel matrices and investigate controlled release of nanocages, advancing the potential of these

materials for programmable vaccine delivery and other immunotherapeutic applications.

Lily Coral CC'28, Music, Psychology

Faculty Mentor(s) or Supervisor(s): Alfredo Spagna
Title: Can Music Alter Future Perception and Imagination? The Impact of Musical Emotion on Multisensory Binding and Imagination

Abstract: This research examines the links between music, human perception, and imagination using a psychological phenomenon known as the ventriloquism effect. This effect occurs when an auditory stimulus is perceived to be localized in the same part of space as an in-sync visual stimulus (1). The ventriloquism effect is used as a model for the study because it also occurs when the visual stimulus is imagined (2). A helpful example of the effect is when people watch a movie with speakers located at two different parts of the room but still perceive the audio as coming from the characters on screen (1). Other researchers have shown that the effect can be altered by prior emotional learning, but researchers have yet to investigate how musical emotion impacts the ventriloquism effect (3). Further, the heterarchical model of visual mental imagery theorizes the neural bases of many cognitive aspects of visual imagination but has yet to address emotion (4). This emotional dimension of visual imagination relates to mental health disorders, like intrusive memories in post-traumatic stress disorder (5). Hopefully this research can expand our knowledge of this highly relevant but underresearched dimension of imagination. The study consists of a preliminary auditory localization phase, an emotional learning phase, and a set of real and imagined ventriloquism effect phases. For the emotional phase, participants either listened to human-performed music, artificial intelligence generated music, or a control beep. Performance data was collected for each task. Data collection is still ongoing and results are only preliminary.

Josh Corn SEAS'27, Applied Physics

Faculty Mentor(s) or Supervisor(s): Sebastian Will
Title: Laser Focus: Quantum Control over Sr-88 Atoms using ECDLs

Abstract: Atoms are the fundamental units of matter, and all physical measurements (time, mass, length, and other SI units) ultimately reference atomic properties. But how do we measure and study atoms themselves? Atoms are quantized: they can only exist in a number of specific energy states. A laser, carefully tuned to the exact energy difference, can drive an atom from one state to another. This project encapsulates the assembly, calibration, and monitoring of an External Cavity Diode Laser (ECDL) tuned to 707 nm, corresponding to the 3P2 to 3S1 transition in Strontium-88 atoms. The ECDL uses a diffraction grating - a mirror that separates light into certain wavelengths - to filter and stabilize the laser frequency. For finer control, the system connects to a piezoelectric actuator, temperature controller, and current controller, all integrated onto a soldered circuit board. The laser beam is manipulated using conventional optical elements and collimated into a Hollow Cathode Lamp (HCL), a glass tube containing hot strontium gas. When the laser is tuned precisely, strontium atoms absorb the light and transition to an excited state, blocking transmission through the lamp and confirming laser accuracy. To counteract Doppler effects from fast-moving atoms, Saturation Absorption Spectroscopy is also used. Ultimately, a continuously running Python program on a Raspberry Pi closely monitors the laser wavelength and sends alerts if it drifts off-target. Precise control over strontium's energy levels has profound applications in atomic physics, including laser cooling, coherent state manipulation, and using atoms for novel quantum technologies.

Eva Cullen CC'27, Applied Mathematics, Astrophysics

Faculty Mentor(s) or Supervisor(s): William Menke
Title: Synthetic Rayleigh Wave Tomography of the Northern Appalachian Mantle Anomaly

Abstract: Recent studies have identified a slow velocity anomaly in the upper mantle beneath the Northern Appalachians known as the NAA. In this work, we examine how this structure alters the propagation of fundamental mode Rayleigh waves. Interpreting such wave behavior with real earthquakes is difficult because Earth's complex structure obscures the influence of a single anomaly. To overcome this limitation, we generate synthetic waveforms with SpecFEM simulations to investigate scattering, focusing, and phase delay effects tied specifically to the NAA. Rayleigh waveforms are windowed and Fourier transformed to extract amplitude information, while phase velocities are estimated using the three station phase difference method after Delaunay triangulation of the array. We test three models: a 200 km semispherical anomaly, a semisphere with a narrow cylindrical extension (stacked model), and a 400 km anomaly built to approximate observed NAA parameters. Our simulations demonstrate velocity perturbations across multiple periods. At 32 s, amplitudes are lower, while at 100 s they increase significantly, showing a sign reversal above the anomaly. Higher amplitudes uprange indicate wave focusing, while at 100 s the anomaly shifts downrange by ~100 km. The

stacked structure amplifies perturbations at 32-50 s, while the broader 400 km model reproduces features consistent with real event data.

Audrey Czarnecki CC'27, Biology

Faculty Mentor(s) or Supervisor(s): Remi Creusot
Title: Identification and Comparison of Hematopoietic Stem and Progenitor Cell Subpopulations in Mouse Tissues and Blood

Abstract: Type 1 diabetes (T1D) affects nearly 10 million people worldwide and arises from autoimmune T cell attacks on pancreatic β-cells. Repeated autoantigen presentation by modified hematopoietic stem and progenitor cells (HSPCs) has been tested for T1D prevention in non-obese diabetic (NOD) mice. Purification and mobilization of these cells remain obstacles for engraftment and treatment. These studies aim to compare subpopulations of HSPCs for use in long-term tolerance induction. We compared bone marrow from NOD and IDEAS mice (containing a disease-relevant antigen-encoding transgene) and analyzed blood, bone marrow, and spleen from NOD mice treated with and without AMD3100 and BIO5192 HSPC-mobilizing drugs. We found no significant differences in cell populations between NOD and IDEAS mice, likely owing to their difference in the transgene's presence, resulting in dramatically reduced incidence of disease in IDEAS mice. A likely subpopulation of HSPCs was identified as CD201+ CD27+ c-Kit+. No significant differences were found between HSPC subpopulations in mobilized versus non-mobilized blood and spleen. In bone marrow, increased expression of CD150 was observed for non-mobilized cells while there was an increase of CD150+ CD201+ CD27+ cells among mobilized cells. The latter is likely to describe HSPCs in NOD mice, and the HSPCs may not leave the bone marrow but remain nearby until flushed for collection. CXCR4 expression increased in mobilized bone marrow, possibly to resist drug mobilization. Future studies will be conducted to purify Sca-1+ c-Kit+, CD27+ CD201+, and triple positive cells for injection into NOD mice to determine treatment efficacy for each subpopulation.

Vinicius da Silveira Lanza Avelar CC'26, Chemistry, Physics

Faculty Mentor(s) or Supervisor(s): Riccardo Comin
Title: Band structure and magnetic phase control through intercalation, electrostatic and chemical doping in transition metal oxyhalide $NbOCl_2$

Abstract: The engineering of flat electronic bands, where electron kinetic energy is quenched, is a central pursuit in condensed matter physics for realizing exotic correlated states like Wigner crystals, unconventional superconductivity, and ferromagnetism. In this context, $NbOCl_2$ has emerged as a key material, hosting a flat band near the Fermi level, according to DFT calculations, on top of ferroelectric order and a wide array of strong nonlinear optical responses. A critical challenge in exploring these interesting properties relates to its wide bandgap, typically out of the energy range of most common lasers. Here, attempts are made to chemically tune the electronic properties of $NbOCl_2$ by a few different methods. First, the synthesis of a doping series, $Nb_{1-x}M_xOCl_2$ (M = Mo), was attempted, substituting the Nb metal site with Mo as it is predicted to reduce the bandgap, thereby enhancing optical accessibility. Simultaneously, multiferroicity in this system is explored by attempting to induce magnetism through hole-doping, generating intrinsic flat band-related magnetism, and through magnetic ion intercalation. Results show this material is extremely sensitive to chemical compositions, and experimental difficulties pose a challenge to the attempted experiments. Further exploration is needed to achieve the desired results, but success will open pathways to probe and harness this system's strong optical nonlinearities and dichroism with ultrafast spectroscopy, advancing its potential for applications in quantum technologies and spintronics.

Aruna Das CC'26, Biology

Faculty Mentor(s) or Supervisor(s): Martin Chalfie
Title: Investigating a C. elegans Mutant with an Imbalanced Nervous System

Abstract: In any nervous system, different cells and components must be coordinated so that one particular stimulus results in one particular outcome. We can learn more about this balance and the mechanisms that govern it by observing organisms where it is faulty. Caenorhabditis elegans, a compact nematode that exhibits diverse touch behaviors and has a known cell lineage, neural connectivity, and complete genome sequence, is an ideal model for studying the reflex system underlying mechanosensation. Recently, Terese Lawry in the Chalfie Lab identified a C. elegans strain (VC40578) that exhibited an abnormal response to touch. In wild-type worms, the most recent response dominates, but in mutants with the mutated gene, signals from the anterior sensory system overpower those from the posterior system, preventing it from initiating forward movement. VC40578 also has a longer response to a head touch than N2, indicating that anterior sensory signaling is overactive in general. The mutated gene likely plays a crucial role in balancing and evaluating responses when C. elegans encounters conflicting stimuli rapidly. VC40578's defect is likely in the signaling between components of C. elegans' three-neuron reflex circuit. Touch receptor

neurons detect gentle touch, and then interneurons communicate estate information to motor neurons, which then initiate muscle contractions leading to either forward or backward movement. As VC40578 can detect gentle touch and are mobile, the first and last components of this circuit are presumably functional, and the strain's defect is likely in connections involving the interneurons involved in backward movement. To uncover the genetic basis of the phenotype, I outcrossed VC40578 with wild-type animals, reisolated the mutants, and performed whole-genome sequencing on the reisolated mutants. From this method, I identified nine candidate genes on Chromosome V. Among them, frpr-5—a gene predicted to encode a GPCR responsive to FMRFamide-like peptides—seemed the most promising candidate as proteins of this type are known to play a role in neuronal signaling, frpr-5 is expressed in the touch-circuit interneuron AVA, and previous research had indicated that the null frpr-5 induces a minor touch defect when animals are touched on the head and then tail. This past summer, I generated two CRISPR lines with VC40578's frpr-5 mutation in an N2 background. Preliminary tests indicate that they display the same phenotype as VC40578. Further investigations into frpr-5's role in the touch circuit could contribute to a deeper understanding of how C. elegans and other organisms maintain proper sensory response coordination. The VC40578 strain demonstrates how disruptions in neuromodulation rather than altered circuitry can influence behavioral outcomes.

Debpriya Das GS'26, Biology

Faculty Mentor(s) or Supervisor(s): Shah Ali
Title: The Trade-Off of a Beating Heart: How Cardiomyocytes Sacrifice Regeneration for Strength

Abstract: The human heart can beat continuously for decades, yet it has very limited ability to regenerate after injury. This lack of regenerative capacity underpins the progression of heart failure, which remains a leading cause of illness and death worldwide, affecting over 64 million people and responsible for one in nine deaths annually. Understanding why the adult mammalian heart cannot heal itself as effectively as other tissues is a major challenge in cardiovascular biology. One leading explanation is that, shortly after birth, heart muscle cells (cardiomyocytes) become polyploid, meaning they duplicate their DNA without dividing. In contrast, animals such as zebrafish, which maintain mostly diploid cardiomyocytes, can regenerate heart tissue efficiently. This raises the question of why mammals evolved to have polyploid cardiomyocytes and whether retaining diploid cardiomyocytes could improve regeneration without harming heart function. In this study, researchers used a genetically engineered mouse model in which cardiomyocytes remain mostly mononucleated and diploid into adulthood. They compared these cells to normal polyploid cardiomyocytes and found that diploid cardiomyocytes experienced significantly more DNA damage, as measured by comet assays. This suggests they may be more vulnerable to stress and could grow more slowly, predisposing the heart to dysfunction over time. These results reveal polyploidization as an adaptive trade-off, favoring long-term heart stability at the cost of regeneration and offer insight for future strategies to safely promote heart repair without compromising function.

Reema Dawar SEAS'27, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Kristin Myers
Title: Characterizing the Heterogenous Mechanical Properties of the Human Cervix to Better Understand Mechanisms of Preterm Birth

Abstract: Preterm birth (birth before 37 weeks of pregnancy) is the leading cause of neonatal mortality worldwide and a major global health concern. The cervix plays a key role in pregnancy, acting as a physical barrier holding the fetus in place and then softening to allow delivery. In spontaneous preterm birth, the cervix softens, shortens, or dilates prematurely, leading to mechanical failure that can trigger an early delivery. Investigation into the mechanical properties of the cervix can help explain spontaneous preterm birth, but these properties have not been fully characterized yet.
This project developed a protocol and 3D-printed dish to measure the cervix's mechanical properties along its entire length. An instrument called the nanoindenter was used to perform indentation tests on human cervix tissue to measure local mechanical properties. Because the nanoindenter could only test small sections at a time, each cervix sample was divided into two halves and tested separately. The data was accurately combined to create a continuous "map" of cervical mechanical properties, making it possible to compare how they vary along its length. Prior to this study, mapping mechanical properties along the length of the cervix had not been achieved in this field. In the future, these measurements can be incorporated into 3D models to better represent cervical behavior during pregnancy. Such models could help researchers and clinicians understand how changes in the cervix's mechanical properties contribute to spontaneous preterm birth and eventually improve prediction and prevention strategies.

Mitchell Dees CC'26, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Peter Canoll

Title: Intraoperative 5-Aminolevulinic Acid (5ALA) Fluorescence Reveals Tumor and Immune Heterogeneity at the Glioblastoma Margin

Abstract: Glioblastoma (GBM) is an aggressive Grade 4 brain tumor with poor prognosis. Surgical resection aims for maximal tumor removal, but precise margin discernment is challenging due to infiltrative growth. Extent of resection is a significant determinant of survival, optimized using fluorescence-guided surgery. 5-Aminolevulinic Acid (5ALA) is a heme-synthesis intermediate that induces fluorescence in GBM tissue intraoperatively. Although routinely used, its behavior at the tumor margin is poorly understood. Recent studies revealed 5ALA labeling is not exclusive to tumor cells and may extend to some non-tumor cells. This study compared 5ALA+ and 5ALA- cells in the microenvironment of the infiltrative margin. MRI-localized biopsies were collected from the non-contrast-enhancing margin and labeled 5ALA+ or 5ALA- intraoperatively. Biopsies underwent single-nucleus RNA sequencing and immunofluorescence for validation. 5ALA+ tumor regions show increased cell density ($p = 0.028$) and tumor cellularity ($p = 0.037$). The actively dividing cell percentage and fraction of proliferative tumor cells were higher in 5ALA+ regions ($p = 0.003$ and $p = 0.016$). P2RY12+ microglia, a marker of homeostatic microglia, were significantly downregulated in 5ALA+ tissue ($p < 0.001$). Tumor cells in the 5ALA- margin, left behind after surgery, are less proliferative and less inflamed, suggesting evasion of immune activation. These findings help provide insight into why residual GBM cells resist therapy and drive recurrence. Ultimately, 5ALA fluorescence identifies areas of tumor infiltration and immune activation, informing intraoperative decision-making and optimize the extent of resection.

Jenny Deng CC’27, Biochemistry

Faculty Mentor(s) or Supervisor(s): Annelise Mah-Som
Title: Using DAF-seq to study chromatin accessibility in regulatory regions of cancer susceptibility genes

Abstract: Inherited cancer risk is only partially explained by rare coding variants currently detectable through clinical gene panels. We hypothesize that a significant proportion of the unexplained risk arises from regulatory and epigenetic alterations in the promoter regions of oncogenes and tumor suppressors. Thus, we aim to develop a targeted approach using deaminase-assisted single-molecule chromatin fiber sequencing (DAF-seq) - a method for assessing chromatin accessibility and DNA-binding protein occupancy at specific loci through selective deamination - to study the regulatory regions of 37 cancer susceptibility genes. We successfully mapped chromatin accessibility of the regulatory region across multiple genes: BRIP1, APC1A, PTEN, RAD51C, SDHB, SDHC. DAF-seq results were consistent with orthogonal Fiber-seq datasets, and autocorrelation analysis showed periodic nucleosome spacing, confirming high-quality accessibility signals. Sequencing results were also obtained for BRCA1, BRCA2, and MSH3, but analysis indicated off-target primer binding as a key limitation requiring further optimization. Our results demonstrate the feasibility of DAF-seq for targeted profiling of cancer gene promoters. Future work will extend this targeted panel to all 37 cancer susceptibility genes, with the goal of enabling haplotype-specific detection of promoter alterations. This will allow the detection of germline epigenetic variants and allele-specific regulatory alterations in promoter regions that are not captured by current cancer gene panels.

Chris Deng CC’26, Applied Mathematics, Physics

Faculty Mentor(s) or Supervisor(s): Maxim Prigozhin
Title: Cathodoluminescence for Multicolor Electron Microscopy

Abstract: Electron microscopy offers nanoscale resolution to image cellular ultrastructure such as membrane and small organelles, and has been crucial in important advances in modern bioimaging and cellular biology. However, it results in grayscale pictures that cannot resolve distinct biomolecules—key to visualizing complex intracellular dynamics and decoding biological organization. By exploiting materials that emit photons when excited by an electron flux via cathodoluminescence (CL), it is possible to achieve a multicolor electron microscopy modality that captures colorful photos of cellular architecture at the nanoscale. We investigate the limitations and advantages of CL-based imaging using Monte Carlo simulations of electron scattering in different materials that exhibited CL, such as cell and rare-earth nanoparticles. These materials can serve as CL tags for biomolecules. We examine the electron interaction volume and the lateral and depth electron energy loss curves under different beam energies to infer the distribution of CL generation when imaging with a scanning electron microscope (SEM). Our analysis provides the energy-dependent CL-imaging resolution for embedded features in an SEM. We further compare it with existing modes of SEM imaging using secondary electrons and backscattered electrons and attempt to compare the quantum efficiencies of these modalities of bioimaging.

Sophia Deng CC’26, Biology

Faculty Mentor(s) or Supervisor(s): James L. Manley
Title: A Nucleolar lncRNA-Encoded Protein RIEP Impairs DNA Damage Repair and Promotes Genomic Instability

Abstract: Long noncoding RNAs (lncRNAs) are increasingly recognized as regulators of nuclear organization and genome stability. The nucleolar lncRNA PAPAS, transcribed antisense to rRNA genes, regulates rDNA transcription during stress and encodes a 25 kDa protein, RIEP (Ribosomal IGS Encoded Protein). RIEP localizes to both nucleoli and mitochondria and has been implicated in the heat shock–related DNA damage response, but its role in DNA double-strand break (DSB) repair remains undefined. It was hypothesized that RIEP impairs timely and accurate DSB repair, leading to persistent DNA damage and genomic instability. Upon induction of DNA damage, RIEP-expressing cells exhibited a significantly higher number of micronuclei than controls, reflecting elevated genomic instability. Using immunofluorescence staining for γH2AX, RIEP overexpression was found to result in significantly higher levels of DNA damage foci following UV or camptothecin (CPT) treatment. Functional reporter assays further demonstrated that RIEP significantly reduces the efficiency of both homologous recombination (HR) and non-homologous end joining (NHEJ), the two major DSB repair pathways. Together, these findings support a model by which RIEP acts as a negative regulator of DSB repair, compromising both HR and NHEJ efficiency and promoting persistent DNA lesions. By identifying a stress-responsive nucleolar protein that directly influences DNA repair capacity, this work expands current understanding of how nucleolar factors contribute to genome maintenance. Although the physiological and pathological contexts of RIEP expression remain undefined, the results suggest that RIEP represents a previously unrecognized modulator of DNA repair fidelity and a potential link between nucleolar stress responses and genome instability.

Adrita Dhar CC’28, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Gamze Gürsoy
Title: Mapping Chromatin Organization in Amyotrophic Lateral Sclerosis

Abstract: Amyotrophic lateral sclerosis (ALS) is a rare, progressive neurodegenerative disease where the loss of motor neurons in the brain and spinal cord leads to muscle weakness, paralysis, and respiratory failure. Although numerous genetic risk factors for ALS have been identified, how these mutations drive neurodegeneration remains unclear. Recent studies suggest that chromatin architecture—the three-dimensional arrangement of the genome—plays an essential role in regulating gene expression, and its disruption can lead to widespread transcriptional changes that contribute to various diseases. We hypothesize that ALS-associated gene misregulation may arise from alterations in chromatin interactions, particularly changes in how non-coding variants affect regulatory element–gene contacts. To test this hypothesis, we generated chromosome conformation data from the prefrontal motor cortex of ALS patients and control samples from normal human brain tissues. We optimized the experimental protocol for postmortem human brain tissue to improve data quality. We refined MNase digestion conditions, achieving ~70% mononucleosome yield as confirmed by TapeStation analysis. We further compared ligation strategies, finding that splitting the proximity ligation into two reactions produced higher library complexity than a single-reaction approach. Finally, quality control metrics, including library size distributions and iSeq data, guided adjustments produced robust, deeply sequenced libraries. This approach allows us to map differences in genome organization, from large-scale compartments to fine chromatin loops, and identify patterns of disorganization unique to ALS. By integrating structural and genomic analyses, our work seeks to clarify how genome architecture contributes to gene regulation in ALS and to identify potential new targets for therapeutic intervention.

Mei Dulabic Chalfe CC’27, Biology

Faculty Mentor(s) or Supervisor(s): Ryan Gaudet
Title: Defining the Necessary and Sufficient Role of CIITA in Endothelial Cell Antigen Presentation

Abstract: The adaptive immune response is initiated by antigen presentation on major histocompatibility complexes (MHCs) to activate circulating immune cells. Surface presentation of extracellular antigen on class II MHC (MHC-II) by professional antigen-presenting cells (proAPCs) can trigger robust immune responses. Yet, even though proAPCs are significant contributors to these MHC-II responses, the human body contains far more structural cells than specialized immune cells, creating a large space that pathogens could exploit. To counter this, the immune system recruits structural cells like endothelial cells (ECs), which line blood vessels, to act as temporary semi-professional APCs. Unlike proAPCs, which constitutively express CIITA— the class II transactivator that serves as a master regulator of MHC-II, endothelial cells require interferon-gamma (IFN-γ) signaling to induce MHC-II surface expression and antigen presentation. This project addresses a fundamental question: Is CIITA necessary and sufficient for IFN-γ–induced MHC-II expression in human ECs? To test necessity,

CRISPR/Cas12a was used to generate CIITA knockout (KO) lines in human dermal microvascular endothelial cells (HDMVECs), and loss of IFN-γ–induced MHC-II was quantified by flow cytometry. To test sufficiency, parallel cultures were transduced with lentiviral vectors to overexpress CIITA in the absence of IFN-γ, testing whether CIITA alone could drive MHC-II expression. Early findings suggest that MHC-II expression in HDMVECs is largely dependent on CIITA, supporting its role as a master regulator of IFN-γ–induced antigen presentation in non-immune cells. This work establishes a foundation for understanding how non-immune cells contribute to immune regulation, with implications for transplantation and cancer immunotherapy, while also highlighting the need to investigate how EC antigen presentation integrates into broader immune responses.

Arinze Ejeh CC'26, Psychology

Faculty Mentor(s) or Supervisor(s): Helen H. Lu
Title: Evaluating Probiotic Bacteria Behavior for Oral Delivery and Application

Abstract: The oral cavity is home to a diverse community of bacteria that play a crucial role in maintaining oral health. When this balance is disrupted, it can lead to conditions such as gingivitis and, if untreated, more severe periodontal disease. While antibiotics are commonly used to treat these infections, they can also negatively affect beneficial bacteria (probiotics). Probiotics offer a potential alternative treatment to these oral diseases, therefore, we hypothesized that by creating an accurate in vitro model that mimics the oral environment, we can study probiotic interactions with gingival tissue. To model these interactions, we used probiotic strains Escherichia coli Nissle 1917 and Lactococcus lactis, testing their growth across varying concentrations of artificial saliva combined with standard growth media to mimic the oral environment. Both strains demonstrated the ability to grow in solutions containing up to 99% artificial saliva, though higher saliva concentrations (i.e., less growth media) showed slowed growth and reduced bacterial numbers. Subsequently, as a preliminary simulation of gingival tissue, we prepared 25% w/v gelatin hydrogels crosslinked with microbial transglutaminase and fabricated electrospun scaffolds composed of gelatin and PLGA. Probiotics were then seeded on the scaffolds and incubated at 37°C for 18 hours before integration with the hydrogels. Results indicated that the majority of probiotics localized onto the hydrogels, demonstrating a clear affinity for the hydrogel. Notably, E. coli exhibited a somewhat higher rate of transfer compared to L. lactis. These findings serve to enhance our understanding of probiotic bacterial behavior in oral environments and provide valuable insights for the development of dental biomaterials aimed at preventing microbial infections and supporting oral health by mitigating diseases such as gingivitis and periodontitis.

Malek Elashry CC'26, Classics, Jake Richards CC'26, Classics, Mathematics, Ari Yao CC'26, Classics, Comparative Literature & Society

Faculty Mentor(s) or Supervisor(s): Marcus Folch
Title: Imprisonment in the Ancient Greek World

Abstract: This research project focuses on the study of the language of imprisonment in Greek literature from the archaic period to circa 300 CE, in conjunction with Professor Marcus Folch's (Classics, Columbia) new book project, Bondage, Incarceration, and the Prison in Ancient Greece: A Cultural History. A major methodological approach included building a comprehensive database of language concerning the Ancient Greek prison across genre and time, with references to imprisonment, physical binding, and/or punishment ranging from literary images to accounts of historical events and fragments of laws. Such a database gives new insight not only into the state of the Athenian prison in the 5th century BCE (where similar histories tend to begin), but also how the prison was constructed, maintained, and guarded in the wider cultural and literary consciousness of ancient Greece. This project attempts to make two significant contributions to future classical scholarship. The first is a more accurate timeline, both of the historical circumstances of the Greek prison's existence and its various conceptualizations in the literary and rhetorical imagination. The second, and perhaps wider-reaching, is the creation of dynamic, open-source reference databases and searchable spreadsheets, comprising both primary source material and secondary literature and commentaries, that will be made available in due time to the scholarly community. The other focus for this project was to be a training ground for how generative AI models might be used to analyze primary source documents in Ancient Greek, as well as to organize historiography of the Ancient Greek prison.

Paula Enriquez GS'27, Psychology

Faculty Mentor(s) or Supervisor(s): Marla Geha
Title: Externalizing Symptom Severity is Associated with Emotion Regulation in Youth

Abstract: This study examines mechanisms of emotion regulation in late childhood and the potential intergenerational influence of parental regulation. We focused on two central facets of emotional functioning: regulation success, defined as the ability to effectively downregulate emotional responses, and emotional reactivity, defined as heightened sensitivity to affective stimuli. The primary aim was to assess whether individual differences in these processes were associated with externalizing symptom severity, including maladaptive aggression, noncompliance, and irritability. A secondary aim was to evaluate whether parental emotion regulation moderated the relationship between children's regulatory capacities and their symptom profiles. Participants included 44 child–parent dyads, with children ranging from 9 to 12 years old. Data were derived from parent- and child-report questionnaires assessing cognition, externalizing symptoms, and emotion regulation, along with a laboratory-based cognitive reappraisal task administered during functional magnetic resonance imaging (fMRI). Results indicated that greater externalizing symptom severity was significantly associated with reduced regulation success in children, while reactivity showed no robust association. These findings underscore the central role of regulatory impairments in youth psychopathology and support the conceptualization of emotion regulation as a transdiagnostic mechanism. Implications include the need for interventions that directly target regulatory skills in children, as well as future work to clarify the moderating role of parental regulation in shaping developmental trajectories of risk and resilience.

Emily Epstein SEAS'27, Applied Physics

Faculty Mentor(s) or Supervisor(s): Carlos Paz-Soldan
Title: Power Systems Development for the CUTE Tokamak

Abstract: A modular high current switching power supply system is currently under development for the Columbia University Tokamak for Education (CUTE) experiment in construction at Columbia University. Each of the 28 independent poloidal/OH and toroidal field (2 parallel circuits) coils will be driven by 56 0.9 MVA (1kA, 900V) insulated-gate bipolar transistor (IGBT) H-Bridge switching power amplifiers (SPAs) previously used for the HIT-SI family of devices. A new digital control system utilizing the Raspberry Pi Pico microcontrollers to control each high-power SPA allows precise driving of currents for each poloidal and toroidal field coil. Feed-forward operation is planned for initial operations with proportional-integral differential (PID) feedback for coil current using onboard digitizers and a minimum control loop period of 20µs. Future updates to the system will support realtime control through serial datalinks from a central control system. Initial low power tests have demonstrated the Raspberry Pi Pico and PID control program's ability to consistently output desired current waveforms with an inductive test load. Design, implementation, and plans for the overall power system will also be presented.

Su Ertekin-Taner CC'26, Creative Writing, Sociology

Faculty Mentor(s) or Supervisor(s): Jonathan Rieder
Title: Scripts of Hegemony: Framing Gender-Based Violence in Turkish Print Media

Abstract: This study examines how gender-based violence (GBV), specifically violence against women (VAW) and domestic violence (DV), is framed in Turkish print newspapers during the year before and after Turkey's withdrawal from international anti-gender violence accord, the Istanbul Convention. Anchored in literature on media framing in authoritarian regimes, the analysis considers how the Justice and Development Party (AK Parti) has reshaped the media landscape and public cultural scripts through economic coercion, legal intimidation, and direct censorship—mechanisms which forcibly narrow discursive norms. Through an in-depth content analysis of select articles in one prominent, legacy Turkish newspaper—the Daily Sabah—this study investigates how narratives of gender-based violence are constructed, which actors are foregrounded or omitted, and what rhetorical strategies are deployed to frame gender-based violence. Findings suggest that political alignment or proximity and state pressure play a notable role in shaping how gender-based violence is articulated in the news. Turkey's exit from the Istanbul Convention, marking a rupture in its previous legal commitments to gender equality, provides a revealing backdrop for such trends in media discourse. By situating media framing of GBV within Turkey's broader political and legal transformations, this study contributes to the sociological understanding of how gendered violence is discursively negotiated in illiberal media environments.

Jordan Faulk GS'26, Philosophy

Faculty Mentor(s) or Supervisor(s): Akeel Bilgrami
Title: Individual Ethical Behavior Interval

Abstract: A visual representation of McDowell's studies on Aristotle's Nichomachean Ethics, with further consideration made and displayed based on the works of Wittgenstein and Lukacs as well as collective works in the Biological Anthropology and Neuroscience communities. What is explained

solely as 'cause and effect' or 'action and end', can be explained endlessly in a manner that is too tedious for major consumption. Dually, what can be explained of these instances in terms of pure objective science is also overly compensative for what the modern leader and decision maker may need to encumber in their mind and logical thinking. By reiterating the conflict of definitive stances, rational and irrational, in a coherent conversation of normative orthodoxy, while still entertaining objective empiricism, I have created a mentally-digestable interval system as to be applied atomistically to the levels of society, and its respective debates, today. While the depth of the research will not be on display, the skeleton will be - this image provides context to the ongoing aspects of developmental psychology, and can be applied to mathematical thoughts as a necessary aspect of what is needed to go past relative objective knowledge into a realm of true absolutes, starting from what we hold in front of ourselves indefinitely, the present and our experience.

Ariella Garren CC'25, Applied Mathematics, Marie Tarazi CC'26, Applied Mathematics

Faculty Mentor(s) or Supervisor(s): George Dragomir
Title: Orion: Inferring Evolutionary Fitness of Proteins from Genotype Trajectories

Abstract: Orion is a computational framework that predicts the evolutionary fitness of proteins by analyzing genotype frequency trajectories from directed evolution experiments. Measuring fitness of evolving gene variants from full-length genotypes is limited by the sequencing cost and complexity of the process. In 2021, a novel machine learning method named Evoracle was able to reconstruct the full genotype of variants using short-read (possibly noisy) sequences from directed evolution experiments. Orion leverages Evoracle's public dataset, which contains genotype and fitness data derived from Phage-Assisted Continuous Evolution (PACE) experiments on the Cry1Ac gene, to model how gene variants evolve and to infer their relative fitness from time-series data. Fitness is the ability of a variant to survive and reproduce in a given environment, inferred from its relative frequency in a population. There is a direct link between a variant's fitness and its reproductive success, which is measured by the genotype's frequency. After data cleaning and thresholding, features such as linear growth, median time appearance, and lifespan length were extracted for each genotype. Correlation analyses revealed that median timepoint and early growth are the strongest predictors of fitness, while lifespan length was strongly negatively correlated with genotype fitness. Using features that strongly correlate with fitness, a semi-quadratic regression model was generated to predict fitness. Similar to the nebula, Orion identifies the 'rising stars' - variants with strong early growth but not yet dominant. This highlights the potential for forecasting evolutionary trajectories before complex evolutionary dynamics, providing a scalable and interpretable tool for studying protein adaptation and variant emergence.

Beruktawit Gebreamlak CC'26, Physics

Faculty Mentor(s) or Supervisor(s): Carlos Paz-Soldan
Title: High-Temperature Superconducting Non-Planar Coil Development: From Design to Cryogenic Testing

Abstract: The Columbia Stellarator eXperiment's (CSX) objective is to upgrade the Columbia Non-neutral Torus to a quasi-symmetric stellarator incorporating high-temperature superconducting (HTS) magnet technology. Stellarators are a favorable path toward sustainable fusion energy due to their steady-state operation. This presentation focuses on the design, fabrication, and testing of the HTS magnets. The design process incorporates quasi-symmetric field shaping while minimizing torsion and strain on the HTS tape, recently achieving a calculated strain of 0.22%. The design is used to produce a non-planar bobbin following the shape of the HTS. CSX's third coil prototype has recently transitioned from a two-channel double-pancake design to a four-channel design to test windability and achieve higher fields. Furthermore, new retention clamps are redesigned and machined in-house for improved retention during winding and powering of the HTS tape. The magnet test stand features a cryogenic system comprising a cold head, a two-stage magnet interface, copper feedthroughs, HTS-110 leads, and aluminum support structures. Recent engineering upgrades include sapphire spacers between the coil and bracket to provide both thermal and electrical insulation, and the addition of copper braid connections between the first stage and thermal shields to enhance cooling. The current system achieves a minimum operational temperature of 25 K. Additionally, the soldering technique for connecting HTS tapes to copper current leads is under active development.

Ephratah Genet CC'28, Computational Biology

Faculty Mentor(s) or Supervisor(s): Alexander Martinez-Fundichely
Title: Assessing the Detection of Genomic Amplicons in Metastatic Prostate Cancer Patients Using Different Sample Sources

Abstract: Prostate cancer is characterized by a high burden of structural variations that contribute to tumor evolution. In particular, highly amplified

focal regions are crucial because they are associated with overexpression of oncogenes. These amplicons can be found as extrachromosomal DNA or integrated into chromosomes as linear amplicons or complex non-cyclic structures. Understanding the detection limits of these amplicons in castration-resistant prostate cancer (CRPC) is essential for clarifying their potential association with different subtypes in late-stage prostate cancer. Our project examines how the prevalence of these amplicon types varies across three sources of whole-genome sequencing data: CRPC tumor tissue, cell-free DNA (cfDNA), and cfDNA from patient-derived xenograft (PDX) mouse models. We hypothesize that tumor tissue will provide the highest structural resolution and the most diverse amplicon profile due to more uniform sequencing coverage across the genome, although it reflects only a single tumor site. The cfDNA samples may offer a broader view of tumor heterogeneity across metastatic sites, despite less uniform coverage caused by bias toward nucleosome-protected regions. We expect PDX cfDNA to offer less certainty in amplicon classification due to reduced sequencing depth post cross-species sample processing. We use AmpliconArchitect, a tool that reconstructs and classifies amplicons, to compare the amplicon prevalence across each sample. By comparing the frequency of each amplicon across the sources, we aim to identify which biological sources best capture the structural complexity of CRPC. Furthermore, if any amplicon is consistently detected across all sources, it could serve as a potential genomic biomarker of CRPC subtypes.

Zoie Geronimi CC’26, African American Studies, Computer Science

Faculty Mentor(s) or Supervisor(s): Frank Guridy
Title: Bridging the Justice Divide: Technology As a Tool for Defendant Empowerment

Abstract: Despite the Criminal Justice Act (1964) establishing federal protections for legal representation, systemic inequities in public defense continue to erode procedural fairness for defendants. This project proposes a shift in legal technology: using technology and large language models (LLMs) not to automate judicial processes, but to empower defendants during critical arraignment proceedings. Through the conceptual framework of CourtClarity, a tool designed to deliver accessible legal literacy, this research evaluates its viability via a mixed-method survey of 100 individuals with prior arraignment experience across urban (New York, NY) and rural (Dickinson County, MI) jurisdictions. Participants were recruited through community outreach and online postings and were asked both closed and open ended questions addressing usability, comprehension of arraignment procedures, and perceptions of fairness. The survey was preceded by a short demonstration video of the CourtClarity prototype, ensuring all respondents evaluated the tool on the same basis. Results revealed unanimous willingness to use CourtClarity if available, and strong indications that it significantly improved perceived understanding of the arraignment process, though its influence on plea decisions was more complex. The study concludes that technological tools within the court system can effectively mitigate informational asymmetries when designed as supplements to human counsel, but ethical implementation demands stringent bias audits, transparency protocols, and cultural competence to prevent reinforcement of systemic inequities.

Helene Goldberg GS’26, Psychology

Faculty Mentor(s) or Supervisor(s): Mark Ansorge
Title: Searching for the Fountain of Youth: Exploring the Relationship Between the Serotonergic System and Age-Related Cognitive Decline

Abstract: Aging is characterized by a gradual decline in neurological processes, including the deterioration of the serotonergic (5-HTergic) system (Kanel et al., 2023) and the degradation of higher-order mental processes, such as cognitive flexibility (Lee et al., 2022). The 5-HTergic system is responsible for the production and input of the neurotransmitter serotonin (5-HT), while cognitive flexibility refers to the ability to adapt to changing external stimulus patterns. The weakening of the 5-HTergic system and cognitive flexibility occur simultaneously; however, it is unclear whether there is a causal relationship between 5-HTergic decay and age-related cognitive decline. To explain this phenomenon, 5-HTergic fiber density across the lifespan of Ai32 mice was examined. Using laser confocal microscopy, coronal brain sections from mice at 6, 12, and 18 months of age were stained with GFP and 5-HTT Immuno. ImageJ processing was used to quantify 5-HTergic fiber density in the medial prefrontal cortex (mPFC) and hippocampus. These brain regions were selected because previous work revealed that 5-HTergic fiber pathways to the mPFC are required for cognitive flexibility (A. A. Morgan et al., 2023), and 5-HTergic fiber pathways to the hippocampus are required for memory formation (Teixeira et al., 2018). Results from this study suggest that 5-HTergic fiber degeneration in these regions causes age-related cognitive decline. This demonstrates the potential for future pharmacological interventions in the 5-HTergic system to restore cognitive functions in aging populations.

Daniel Gonzalez SEAS'27, Earth and Environmental Engineering

Faculty Mentor(s) or Supervisor(s): Juliana Silva Alves Carneiro
Title: Doped Vanadium Nitride Catalysts and Protonic Ceramic Reactors for Sustainable Ammonia Synthesis

Abstract: Ammonia is an essential chemical for global food production, energy storage, and transportation. However, the dominant method of production, the Haber Bosch process, operates under extreme conditions of 400 - 500 °C and 100 - 300 bar, making it highly energy-intensive and carbon-emitting. To address these challenges, we are researching electrocatalytic pathways that enable sustainable ammonia production under milder conditions. One promising strategy involves electrochemical systems that convert N_2 and water into NH3 using thermo-electrochemical protonic ceramic reactors at intermediate temperatures (~400 °C) and ambient pressure. Such systems can enhance the kinetics of N≡N bond cleavage while avoiding the severe conditions of Haber-Bosch.
This project focuses on the development of vanadium nitride-based materials, which have emerged recently as promising catalysts for nitrogen activation and ammonia formation. Over the summer, we focused on the synthesis of iron and nickel-doped vanadium nitride via hydrothermal routes and subsequent nitriding. These materials were structurally characterized to understand how transition metal doping influences their stability and reactivity. Experiments evaluated their ability to promote ammonia formation. In parallel, effort was dedicated to fabricating protonic ceramic electrochemical cells that will serve as electrochemical platforms for ammonia synthesis. Different methods for electrode-supported pellets were assessed (i.e., pellet pressing, rolling, and tape casting) to minimize porosity and enhance connectivity, thereby creating reliable functional devices for electrocatalysis. Together, the development of doped VN catalysts and the fabrication of protonic ceramic reactors represent a pathway toward efficient, scalable, and carbon-neutral ammonia synthesis, advancing efforts to decarbonize energy and industry.

Arnia Goode SEAS'28, Mechanical Engineering

Faculty Mentor(s) or Supervisor(s): Chuma Nnaji
Title: Physical Fatigue Monitoring of Construction Workers Using Edge-Based Machine Learning and Wearable Sensors

Abstract: Fatigue is a major concern in the construction industry, as it contributes to reduced productivity, lower work quality, and a heightened risk of accidents. Traditional methods of assessing physical fatigue, such as surveys and questionnaires, are often impractical and unsuitable for real-time monitoring on active construction sites. This research project proposes a smart fatigue monitoring system that combines hardware (Polar H10 heart rate sensor) with software (a mobile application) to classify fatigue levels in real time. A machine learning-based multilayer perceptron model was developed and trained using both objective data, such as heart rate variability (HRV) features and user demographics (age, weight, height, etc.), and subjective data, including self-reported fatigue ratings using the Rating of Fatigue scale. Once developed, the machine learning model was deployed on an edge device (i.e., a mobile app), which collects real-time heart rate data and processes it to predict the worker's fatigue level continuously. When the system detects a high fatigue level, it triggers a vibration alert on the worker's mobile device, prompting timely intervention. The mobile app also includes a page for a manager to be able to see all of their workers' fatigue levels in real time. This integrated solution provides a practical and efficient approach to real-time fatigue monitoring, offering a responsive tool to enhance safety and productivity in construction environments.

Lauren Grae SEAS'27, Materials Engineering, Visual Arts

Faculty Mentor(s) or Supervisor(s): Katayun Barmak
Title: Deep Learning Loss Function and Data Optimization for A.I. Detection of Thin Film Grain Boundaries

Abstract: Understanding microstructural features, particularly grain boundaries, is critical for predicting the mechanical properties, electrical properties, chemical resistance, and overall performance of polycrystalline metals and alloys. Manual tracing of these boundaries remains a time-intensive and subjective process, motivating efforts toward automated and standardized solutions. In this study, a U-Net convolutional neural network architecture was employed to automate grain boundary tracing from bright-field TEM images of polycrystalline thin films. Model training was conducted using three different datasets, each varying in label quality and dataset construction, and evaluated across three loss functions: binary cross-entropy (BCE), mean squared error (MSE), and focal loss. Results from inference testing indicated that models trained with BCE loss and a high-quality, manually retraced dataset ("Grae") produced qualitatively superior grain boundary segmentation compared to models trained on larger and similarly sized, but lower-quality, datasets. These findings suggest that, within U-Net

frameworks, data quality may outweigh data quantity in achieving robust grain boundary detection. Future work should focus on developing more targeted evaluation metrics for segmentation performance and on expanding high-quality datasets, as current assessments rely primarily on qualitative comparisons that may limit generalizability.

Kailyn Grant SEAS’26, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Tal Danino
Title: Engineering Bacteria to Launch and Control an Oncolytic Virus for Targeted Cancer Therapy

Abstract: Oncolytic viruses and bacteria have shown promise as cancer therapies, though both face key limitations. Viral treatments are often neutralized by the host immune system, while bacterial therapies tend to remain confined to the tumor core, limiting their effectiveness against distal tumor cells. To address these challenges, a system called CAPPSID (Coordinated Activity of Prokaryote and Picornavirus for Safe Intracellular Delivery) was developed. In this approach, the bacterium Salmonella typhimurium was engineered to deliver the genome of Senecavirus A (SVA) directly into tumor cells, initiating an oncolytic infection. By encapsulating the virus within bacteria, immune detection was avoided, allowing viral replication and tumor targeting, even in pre-vaccinated hosts. To improve safety and control, the virus was modified to depend on a bacterial protease for activation. A specific cleavage site was introduced into the viral polyprotein, making its maturation dependent on a protease expressed by Salmonella. SVA delivery was also regulated by linking transcription to bacterial intracellular sensing, ensuring viral release occurred only after tumor invasion. Through in vitro and in vivo studies, CAPPSID was shown to promote effective viral delivery, tumor-specific colonization, and tumor regression in both immunodeficient and immunocompetent models, with minimal bacterial presence in healthy tissues. This work demonstrates how microbial systems can be engineered to cooperate in enhancing cancer therapies through improved targeting, immune evasion, and controlled viral spread.

Margot Grøtland CC’27, Environmental Science

Faculty Mentor(s) or Supervisor(s): Yushu Xia
Title: Rapid Soil Carbon and Health Assessment for Land Management in the Hudson Valley

Abstract: Soil is essential for all life on Earth. Yet, the ongoing climate crisis, coupled with unsustainable agricultural practices which create nutrient depleted soils, increasingly threatens the health of our soils. It is crucial to consider how we can both improve soil health and use soil to mitigate climate change. However, conventional, lab-based soil monitoring methods such as wet chemistry can be expensive and time-consuming. Visible spectroscopy has the potential to be a more cost-effective and rapid method for evaluating soil health. In this study, grid-based and strategic GPS soil samples from the Lamont Sanctuary Forest experimental site were collected and processed. Utilizing a Nix Spectro L spectrophotometer, soil samples were non-destructively scanned to collect spectral data across the visible spectrum. These samples were also tested for soil health indicators, including: organic matter content through loss on ignition; calcium, copper, iron, and potassium content through x-ray fluorescence; and pH. With this dataset, prediction models were built to estimate soil health indicators from visible spectral data via machine learning and feature selection methods. Independent validation was then performed through the coefficient of determination (R^2) and the root mean square error (RMSE). Initial results show that soil organic matter content was predicted with good accuracy with an R^2 of over 0.8 using the random forest algorithm. In contrast, this method did not perform as accurately for the other soil health indicators. Detailed results from the model comparisons, along with their implications for land management, will be presented at the symposium.

Isidro Guadarrama Rea CC’27, Biochemistry

Faculty Mentor(s) or Supervisor(s): Hee Won Yang
Title: Investigating Resistance to Multi-RAS(ON) Inhibitors in Melanoma

Abstract: Rat sarcoma proteins (RAS) are a family of small proteins that are often key mediators for cell signaling mechanisms, acting as a light switch with "on" and "off" states. When mutations cause a RAS protein to constitutively stay "on", uncontrolled cell growth occurs leading to cancer. Traditionally, RAS proteins have been considered undruggable, however, recent advances in medicinal chemistry have allowed for the development of multi-RAS(ON) inhibitors, which targets active RAS isoforms. However, the rapid emergence of drug resistance remains a significant barrier in NRAS-mutant melanoma, a subtype of skin cancer characterized by poor clinical outcomes and limited treatment options. Thus, uncovering the molecular and immunologic underpinnings of adaptive resistance in vivo can lead to better clinical strategies. Here, we evaluated the therapeutic response of four NRAS-mutant OSUMMER melanoma cell lines with differing genetic

profiles in immunocompetent mice treated with RMC-7977. Tumor growth revealed heterogeneous resistance patterns, with OSUMMER13 maintaining prolonged sensitivity, while OSUMMER1, OSUMMER5, and OSUMMER10 exhibited adaptive regrowth. Western blot analyses showed that RMC-7977-treated tumors variably retained MAPK and PI3K pathway activity (p-ERK and p-AKT), with concurrent upregulation of NRAS protein in OSUMMER1 and OSUMMER5. Immunostaining revealed inconsistent CD4+ and CD8+ T-cell infiltration across models, suggesting a non-uniform immune response. These findings highlight the complex nature of resistance to pan-RAS inhibition in vivo, implicating both signaling reactivation and tumor-intrinsic heterogeneity in therapeutic escape. This work underscores the need to pair pan-RAS inhibitors with epigenetic or immunologic strategies to enhance treatment durability in NRAS-mutant melanoma.

Alisa Gulyansky CC'28, Comparative Literature

Faculty Mentor(s) or Supervisor(s): Timothy M. Frye
Title: AI Wars: How Russian AI Chatbots Propagate Disinformation about Russo-Ukrainian Relations

Abstract: This project examines censorship and refusal patterns in Russian large language models (LLMs), focusing on YandexGPT and GigaChat in comparison to OpenAI's ChatGPT and Anthropic's Claude. Both Russian systems are owned by companies under direct government influence—Yandex through its Kremlin-aligned governance board and Sberbank as a state-owned institution—making them key case studies of how political oversight shapes AI behavior. Through queries about the Russo-Ukrainian War, corruption, and Ukrainian independence, the study identifies clear trends in how Russian and Western models respond to politically charged topics. Russian LLMs consistently refuse or evade questions about opposition leaders, protest movements, and Russia's role in the war, while offering more straightforward accounts of events that do not implicate the Kremlin. Western models, by contrast, generally address these subjects directly, even while flagging sensitivity. These divergent patterns reveal how Russian LLMs enact the Kremlin's strategy of narrative control through censorship and disinformation: some refusals are categorical, while others take the form of vague generalities or deflections. As Russia adapts propaganda strategies to the digital sphere, this analysis situates LLMs within the Kremlin's broader effort to obscure corruption and reframe Ukraine's past and present. At the same time, the uneven performance of Russian systems underscores disparities in global AI capacity, wherein Russian LLMs remain constrained by political oversight, unvetted training data, and a post-invasion exodus of technical talent. This study highlights the role of AI in sustaining authoritarian information control and asks whether Russia's AI infrastructure is capable of becoming the central tool for state-directed propaganda.

Tanmay Gupta CC'27, Mathematics, Physics

Faculty Mentor(s) or Supervisor(s): Matthew Beidler
Title: Developing a Full Orbit Hybrid Kinetic-MHD Code for Runaway Electron Modeling

Abstract: Nuclear fusion promises a path forward to a future fueled by sustainable energy. One of the leading approaches to nuclear fusion is the tokamak, a donut-shaped device that uses magnetic fields to confine a plasma. In tokamaks, disruptions cause rapidly changing magnetic fields that can drive large inductive electric fields. These fields can accelerate electrons to relativistic speeds and create runaway electron (RE) beams, which can cause significant damage to the tokamak walls. To understand how to mitigate RE beams in future devices, accurate simulations are needed. While magnetohydrodynamics (MHD) captures the macroscopic behavior of the plasma by treating it as a fluid, particle-level "kinetic" descriptions are desired for modeling REs. Prior work (see Lopez et al.) has implemented guiding center (GC) routines from KORC into the NIMROD extended-MHD code, working toward a hybrid kinetic-MHD model. However, full orbit (FO) effects are important for accurately modeling phenomena such as particle deconfinement and orbits in fields varying on the scale of the Larmor radius. We implement a FO particle-pushing algorithm in NIMROD and analytically verify the trajectory for a constant magnetic field. In post-processing analysis, we compare the GC and FO models as well as their conservation properties across a range of timesteps. Furthermore, we profile the FO implementation and subsequently optimize it for GPU acceleration, facilitating the simulation of a large number of particles.

Olivia Hall SEAS'27, Mechanical Engineering

Faculty Mentor(s) or Supervisor(s): Basal Belgücan
Title: Characterization of Sized and Desized Carbon Fibers using Thermogravimetric Analysis and Fourier Transform Infrared Analysis

Abstract: The aim of this project was to analyze the effects of desizing using Thermogravimetric Analysis (TGA) and Fourier Transform Infrared (FTIR) analysis. Using these two methods, we examined the properties of sized fibers, and compared that to the experimental data on fibers that had been desized using the SoxTherm (SoxH) method. The goal of these experiments

was to further understand how desizing alters the morphology of carbon fibers, so that the field of carbon fiber recycling can be further developed. Carbon fiber sizing is one of the last essential steps in the carbon fiber production process, which involves coating the fibers in a sizing agent. While carbon fiber is a lightweight, strong material with excellent mechanical properties, the carbonization process necessarily causes some damage to its structural integrity. This affects the fiber's graphitization and subsequently its wettability, making it "flaw sensitive". The sizing agent acts as a boundary layer between the fiber and polymer matrices, which improves the adhesion between the fiber and the matrix. Thermogravimetric Analysis (TGA) is a "quantitative technique" in which the change in mass of a sample is measured as a function of temperature and time. TGA was used to compare the rate with which mass burns off once carbon fibers have been unsized to that of sized fibers. Fourier Transform Infrared spectroscopy is a widely used analytical technique for identifying and characterizing chemical substances based on their molecular vibrational modes. FTIR provides information about a sample's composition, and was used in this experiment to compare the signature of sized fibers to that of desized fibers.

Ahmed Hamdan CC'28, Biochemistry

Faculty Mentor(s) or Supervisor(s): Virginia Cornish
Title: Design and Synthesis of a Trifunctional Recognition-Solubility-Reporter Scaffold for Bio-orthogonal Click Chemistry

Abstract: Bio-orthogonal chemistry has transformed chemical biology by enabling highly selective covalent reactions in living systems without disturbing native biochemical processes. Among these approaches, strain-promoted azide–alkyne cycloaddition (SPAAC) has emerged as a powerful strategy for modular probe construction. Existing scaffolds, however, are often restricted to bi-functional designs, which limit flexibility for advanced applications in protein labeling, therapeutic delivery, and quantitative assays. This project describes the design and synthesis of a trifunctional modular scaffold that incorporates three essential components: a benzylguanine (BG) recognition motif, a polyethylene glycol (PEG) linker to improve solubility and reduce steric hindrance, and a terminal azide group for conjugation to alkyne-bearing reporters via SPAAC. In the initial step, a BG–amine derivative was coupled to an azido–PEG–NHS ester through nucleophilic acyl substitution, producing a BG–PEG–azide intermediate. This intermediate was subsequently reacted with an alkyne-functionalized fluorophore under copper-free click conditions, yielding a stable triazole-linked BG–PEG–reporter conjugate. The trifunctional design provides a generalizable chemical platform for bio-orthogonal bioconjugation by allowing independent optimization of recognition, solubility, and reporter functions within a single construct. Unlike traditional bi-functional linkers, this architecture enables attachment of diverse cargos, including fluorophores, biotin, peptides, oligonucleotides, nanoparticles, and PROTACs. Such versatility expands the toolkit available for chemical biology, supporting applications in live-cell imaging, affinity enrichment and pull-down assays, intracellular delivery of non-permeable molecules, and quantitative tracking of cytosolic transport. By extending beyond bi-functional systems, the trifunctional scaffold establishes a modular foundation for the next generation of multifunctional probes in chemical biology.

Payge Hardy GS'26, Philosophy

Faculty Mentor(s) or Supervisor(s): Carol Rovane
Title: The Labor of Moral Return

Abstract: Institutions in law, health care, and decision systems treat outcomes as final when no standpoint from which a rational point of view may obtain is present. We see this across (i) early development (infancy; children whose oriented labor toward the good is visible), (ii) cases where an eligible standpoint is not presently available (acute rupture after trauma; cases where multiple rational points of view may obtain within a single life, e.g., Dissociative Identity Disorder), and (iii) protocol-governed settings—triage and risk procedures, bureaucratic processes, and algorithmic systems—in which decisions are reached with no aperture for review by an eligible human standpoint or by a duly constituted group point of view. Such finalization is out of order with respect to reasons: it confers finality where no standpoint for reasons is present, so the commitment to achieve overall rational unity cannot yet be undertaken, collapsing rational influence into merely causal influence. This gives rise to bureaucratic injustice, algorithmic failure, misallocation of care and resources, and the closing of pathways to contest or correct—including the silencing of children's oriented labor. The work states a rule applied ex ante, concurrently, and ex post. No outcome of normative weight may be treated as final unless all of the following obtain: 1. reasons are shown plainly, in terms understandable to those affected; 2. there is an address point for reply: either a responsible human or a duly constituted group point of view for a joint endeavor, capable of all-things-considered judgment and structurally independent of the deciding system—to hear challenges and refuse; and 3. a workable path to reversal or review remains proportionate, set by reversibility of the outcome, severity of harm, and urgency. These checks enact the project's terms: rupture (no eligible standpoint), labor (effort toward

becoming answerable), and return (the first outward step that can be taken up as reasons).

Abigail Hart CC'26, Biochemistry

Faculty Mentor(s) or Supervisor(s): Stephanie Woo
Title: Investigating the Effects of Forchlorfenuron (FCF) on Zebrafish Embryogenesis

Abstract: FCF is a plant growth regulator, used widely in agriculture to increase the sizes of fruits such as kiwis and grapes. It is known that FCF can act as a septin modifier in yeast and vertebrates, but the effects of FCF have not yet been fully investigated in development. Humans share 70% genetic homology with zebrafish, making zebrafish an ideal model organism to explore the biological mechanisms that FCF may affect in humans. Preliminary data has shown that FCF treatment causes shorter body length in developing zebrafish embryos. FCF may interfere with two developmental pathways — the Bone Morphogenic Protein (BMP) signalling pathway, which specifies the dorsal and ventral axis of the embryo, and/or the Wnt planar cell polarity (PCP) pathway, which regulates convergence and extension movements and has previously been shown to interact with septins. We are currently testing whether FCF affects either or both of these pathways, utilizing antibody staining and quantitative PCR for targets within the pathways. These findings suggest that FCF may perturb key developmental pathways, warranting further investigation into its potential developmental toxicity.

Mica Helder-Lindt CC'28, Philosophy

Faculty Mentor(s) or Supervisor(s): Dennis Tenen
Title: Irony, Character, Performance and Subjectivity in Young, Politically Extreme Internet Subcultures and Anti-Democratic Thought in the 2020s

Abstract: The advent of the internet has brought about fundamental changes in how individuals form community, communicate, relate with one another, and express personal identity. As a member of the first generation of children to have grown up native to the digital world we know today, my research project aims to share the insights I've acquired about online youth culture with the rest of the world through a combination of my intuitive, experientially gained cultural knowledge, and systematic research. More specifically, my research focuses on two different internet subcultures, both contained within the broad and interlocking ironic-political sphere of the internet: the primarily alt-right image board "soyjak.party", and the majority left-wing following around the YouTube content creators "JREG" and "wow_mao". Additionally, my research incorporates academic theory both on the definition, use, and operational mechanism of irony more broadly, and the use of language in general. Sourcing a perspective on irony from thinkers like Eco, Wilson and Sperber, and Ducrot and a perspective on language use from philosophers Austin and Grice, and building off of the observations I made in my hands-on research, I go on to argue that the interconnected phenomena of detached irony and "thinking through characters" facilitated by the unique conditions of the internet offer their users both an alternative framework of knowledge and a different conception of truth to that of our conventional democratic institutions.

Aiden Robert Hightower CC'28, Physics

Faculty Mentor(s) or Supervisor(s): Carlos Paz-Soldan
Title: Design of a Conformal Cryostat Prototype for Thermal Regulation in Compact Stellarators

Abstract: The operation of stellarators relies on high-temperature superconducting (HTS) tape, which requires cryogenic conditions that are fundamentally at odds with the extreme thermal environment of confined plasma. A central challenge is maintaining both the large thermal gradient between the superheated plasma and the cryogenically cooled magnetic coils, as well as the precise orientation of the coils that produce confinement. In this project, I designed a conformal cryostat prototype intended to regulate coil temperature while accommodating the unique geometrical constraints of a two-coil stellarator system.
The cryostat was modeled in Fusion360, where a conformal heat shield was CAD-swept around a defined curve corresponding to the coil geometry and designed in sectioned parts suitable for metal 3D printing, with assembly enabled through welding and bolting methods. The device was subsequently fabricated via 3D printing, alongside scaled models of the superconducting coils, to assess mechanical alignment and feasibility. While experimental thermal data have not yet been collected, preliminary outcomes indicate that the prototype achieves correct spatial orientation relative to the coils. This represents a notable improvement over prior cylindrical shield configurations tested within the lab, which lacked precision and adaptability.
The significance of this design lies in its potential to reconcile the intrinsic thermal conflict of stellarator systems by providing a scalable, manufacturable method for cryogenic regulation. Ultimately, conformal cryostat technology could enable compact, low–aspect ratio stellarators with

only two coils, broadening the accessibility and manufacturability of fusion devices.

Margaret Hitt SEAS’28, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Radames J.B. Cordero
Title: Melanin–based Substrate for ISS and Artemis: Optimizing Nutrient Uptake in NASA’s Extra Dwarf Pak Choi

Abstract: This project explores how to grow healthier plants in space to support long-term astronaut missions. Astronauts often depend on packaged foods, which can provide too much iron while leaving out other key nutrients such as calcium, potassium, and magnesium. Too much iron can increase stress in the body, while low levels of other minerals can weaken bones and muscles. To protect astronaut health, NASA seeks crops that take up less iron but more of these essential nutrients. This project investigates how soil-like materials, known as substrates, can be engineered to improve the way plants absorb minerals. One promising material is melanin, a natural compound found in many organisms that can bind metals, hold water, and protect against radiation. By adding melanin to plant substrates, the study examines whether it can reduce excess iron, increase the availability of beneficial minerals, and support healthy plant growth. Using Extra Dwarf Pak Choi, a compact and nutrient-rich leafy green already prioritized by NASA for space farming, this work aims to clarify how growing conditions affect plant nutrition and development, with the broader goal of producing fresh food that meets the needs of astronauts. Insights from this project could help make future crews less dependent on supply shipments from Earth, supporting sustainable living on missions to the Moon, Mars, and beyond.

Sophia Ho GS’26, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Yueqing Peng
Title: The role of neuromodulatory infraslow oscillations in linking sleep and chronic pain

Abstract: Chronic pain and sleep disturbances frequently co-occur, yet the neural mechanisms linking them remain poorly understood. This study investigates how inflammatory pain, at both acute and chronic stages, alters rest-wake behavior, sleep architecture, and neuromodulatory activity, with a focus on acetylcholine. The researchers also assess infraslow oscillations (ISOs), very slow rhythmic fluctuations of brain activity, during non-REM (NREM) sleep. Using a complete Freund’s adjuvant (CFA) mouse model of chronic pain, the researchers combined behavioral tracking, electroencephalography (EEG) recordings, fiber photometry (to measure neuromodulator activity), and immunohistochemistry to examine neural correlates of pain and disrupted sleep. CFA-treated mice exhibited mechanical hypersensitivity alongside prolonged and highly variable rest bouts during the light phase, reflecting sleep fragmentation. These behavioral changes were associated with flattened EEG spectral profiles and increased state transitions. Elevated c-Fos expression (a marker for neural activity) in the contralateral somatosensory cortex, thalamic hyperactivity, and suppressed activity in the ventrolateral medulla indicated pain-induced recruitment of cortical and subcortical circuits associated with arousal and sleep regulation. Notably, photometry revealed increased acetylcholine activity in the medial prefrontal cortex during NREM sleep in CFA mice, suggesting that inflammatory pain interferes with the neuromodulatory rhythms that help organize healthy sleep. These findings support a model in which pain and sleep disturbances reinforce one another, and highlight neuromodulatory pathways as promising targets for integrated therapeutic interventions.

Maya Holloman CC’27, African American Studies, Psychology

Faculty Mentor(s) or Supervisor(s): Danruo Zhong
Title: Impact of Maternal Support on Prenatal Stress of Adolescent Mothers

Abstract: Adolescent mothers experience postpartum depression (PPD) at a much higher rate compared to their older counterparts, with estimates for pregnant adolescents reaching up to 40%. An important step in the prevention of postpartum depression is identifying and addressing stress which occurs during pregnancy. Previous studies have shown that social support is significantly associated with the risk of depression, anxiety, self-harm, and heightened pain intensity during pregnancy. This project seeks to understand the impact of mother-daughter relationships on the stress levels of adolescent mothers’ throughout pregnancy. Using a data set of 135 pregnant adolescents from the Effects of Prenatal Stress and Poor Nutrition on Brain and Cognition study, this secondary data analysis utilizes prenatal mood questionnaires collected over the course of participants’ pregnancies. The results of the study indicate a negative correlation between maternal care and prenatal stress, with the highest correlation being observed during the third trimester of pregnancy, building on previous findings that familial support can act as a protective factor against negative mental health outcomes in pregnancy and postpartum. Understanding the role of familial support in preventing prenatal stress can

also lead to further research regarding maternal mental health among adolescent mothers and the future wellness of their offspring.

Viela Hu CC’27, Art History and Visual Arts

Faculty Mentor(s) or Supervisor(s): John Rajchman
Title: Looking at Matthew Wong: Outsider Art, Mental Illness, Diaspora and Blue 2017-2019

Abstract: "Outsider Art" has experienced explosive commercial growth since the 2000s, with theoretical writing and scholastic research leading public consumption interest. It has developed a set of visual and linguistic vocabulary to identify artists that are isolated from the cultural norms, with many having mental illnesses. The works and life of Asian-Canadian artist Matthew Wong (1984-2019) are described in and limited by such a commercialized vocabulary that ultimately exploits the suffering and demise of the artist for estimate-breaking auction results in the 2020s. This project seeks to critically analyze how Wong is viewed and defined as an artist by his mental illnesses, focusing on his last series of paintings Blue (2017-2019). It identifies three deviations Wong had from the stereotype of outsider artist: engagement with popular rap culture, desire for normative capitalist success and dialogue with global art historical canons. Through examining a series of catalogue essays, Wong's own writings and a film recommended by the Matthew Wong Foundation, Hu argues that the landscapes in Wong's Blue series, inspired by Wong's travelling to Italy and completed in Edmonton, Canada, actually suggests a transnational vision that can be traced to Brazilian geometry abstraction, Martin Kippenberger's Psychbuildings and Metro-Net, and Jack Whitten's abstract Greek Alphabet Series and Atopolis. Wong's borderless world, using Achille Mbembe's term, is one that breaks the boundaries between nations, cultures and mental health in a financialized world that fetishes mental illness.

Acadia Hu SEAS’26, Chemical Engineering

Faculty Mentor(s) or Supervisor(s): Daniel Esposito
Title: Copper Electrodeposition for Defect Characterization in Ultrathin PEM Electrolyzer Membranes

Abstract: Proton exchange membrane (PEM) electrolyzers enable large-scale hydrogen production for renewable energy storage. In these devices, water is split into hydrogen and oxygen, with a thin polymer membrane serving as both proton conductor and gas barrier. Ultrathin membranes (10s–100s of nanometers thick) improve proton transport and reduce ohmic losses compared to conventional membranes, but are highly susceptible to structural defects that cause gas crossover and performance loss. Reliable methods for characterizing these defects are therefore critical for advancing electrolyzer performance. In this study, a copper electrodeposition technique was developed for visualizing and quantifying nanoscale to microscale defects in thin SiO_2 PEM electrolyzer membranes. Copper was electrochemically deposited onto atomic layer deposition (ALD) SiO_2 membrane-coated porous transport layer (PTL) electrodes. Deposited copper selectively accumulated at defect sites, which were subsequently imaged by optical microscopy and analyzed using ImageJ to generate distributions of defect sizes and densities. This approach revealed correlations between defect density and membrane thickness, and assessed the effectiveness of processing treatments that influence membrane integrity. The method provides a reproducible, cost-effective tool for identifying structural vulnerabilities in ultrathin membranes. By linking membrane processing to defect formation, this copper electrodeposition technique enables the design of more robust, efficient PEM electrolyzers, supporting the development of durable and affordable hydrogen electrolyzers.

Connie Huang CC’26, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Christine Ann Denny
Title: Investigating Focused-Ultrasound Mediated Blood Brain Barrier Opening (FUS-BBBO)- induced Adult Hippocampal Neurogenesis (AHN) for Antidepressant Effects

Abstract: Major Depressive Disorder (MDD) is a leading cause of disability, and chronic stress can impair hippocampal function by disrupting neural circuits, reducing synaptic plasticity, and decreasing adult hippocampal neurogenesis (AHN). Many current antidepressants take weeks to become effective and do not work for all patients, highlighting the need for novel, rapid-acting, and non-invasive treatments. Focused ultrasound with microbubbles (FUS-BBBO) can temporarily open the blood–brain barrier, triggering biological responses such as increased growth factor release, neurovascular remodeling, and enhanced AHN. We tested whether FUS-BBBO could produce long-lasting antidepressant effects in a mouse model of stress. Adult male and female mice underwent contextual fear conditioning followed by either hippocampal-targeted FUS-BBBO or a sham procedure. Behavioral tests were conducted six weeks later, and brain tissue was analyzed for AHN markers (BrdU, DCX, NeuN). FUS-BBBO increased both the proliferation and survival of newborn neurons in the hippocampus and

significantly reduced depression-like behaviors, with effects lasting at least six weeks. These findings suggest that FUS-BBBO can promote durable structural and behavioral recovery after stress, supporting its potential as a circuit-targeted therapy for MDD.

Jessie Huang SEAS'27, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Katsuo Kurabayashi
Title: Longitudinal Single-Cell Profiling of CAR-T Cytokine Secretion and Exhaustion via dFAST

Abstract: Chimeric Antigen Receptor (CAR) T cell therapy has emerged as a powerful approach for treating hematologic malignancies, yet its long-term efficacy is often limited by T cell exhaustion and functional heterogeneity. This study investigates how CAR-T cells engineered with 4-1BB, an FDA-approved co-stimulatory domain used in clinical CAR-T therapy, respond to sustained antigen exposure. CAR-T cells are co-cultured with cancer cells over two weeks to model chronic stimulation. Using dFAST (Digital FluoroSpot Amplification for Spatiotemporal Profiling), our lab's recently developed platform for multidimensional single-cell phenotypic and functional analysis, we performed multiplexed measurements of key effector cytokines granzyme B (GzmB) and interferon-gamma (IFN-γ) to assess cytotoxicity and inflammation. In parallel, cells are classified by CD4/CD8 lineage and differentiation state (naïve, effector terminal, central memory, effector memory), and expression of CD25 and CD69 (activation) and PD-1 (exhaustion) is tracked over time. All parameters are captured simultaneously at single-cell resolution, enabling one-to-one correlation of phenotype, function, and temporal dynamics within the same individual cell.
This unified approach allowed us to resolve functional and phenotypic dynamics at single-cell resolution across time. Understanding which subsets retain functionality or are most prone to exhaustion is critical for improving CAR design, guiding cell selection during manufacturing, and enhancing persistence in vivo. These insights are especially relevant as CAR-T therapies expand beyond hematologic cancers into solid tumors, where persistent antigen exposure and immune suppression are more pronounced. Ultimately, identifying markers of potency and durability will help translate CAR-T therapy into more reliable and lasting clinical responses.

Phoebe Huang CC'28, Economics-Philosophy

Faculty Mentor(s) or Supervisor(s): Andrew J. Nathan
Title: Between Nationalism and Pessimism: Chinese Social Media Discourses on the 2025 U.S.-China Tariff Conflict

Abstract: This paper examines the Chinese discursive responses to the 2025 US-China tariff conflict. The study observed over 300 posts and comments on three different Chinese social media platforms—Weibo, WeChat, and Zhihu—and conducted close analysis on 70 of them. The selected post and comments convey personal opinions about the tariff conflict and employ various arguments to support their opinions. The study finds that discourses asserting that the tariff conflict will not harm China, or that China will win/has won, often demonstrate strong belief in the idea of "New China" (新中国). Arguments frequently cite China's economic and manufacturing superiority, perceptions of Trump and Americans as unintelligent, and Chinese history. Rhetorically, these posts and comments are more emotive and exhibit a lack of separation between the self and the country. Both tendencies suggest the presence of strong nationalistic sentiment. Discourses that express the opinion that the US-imposed tariffs could harm China and are uncertain about China's success in the conflict are further categorized into two sub-groups: those supporting retaliatory tariffs and those opposing them. In the former, posts and comments typically argue that China is engaged in a zero-sum game with the US, often citing Trump's fickleness and unreliability as justifications for retaliatory measures. In this group, the widespread use of combative, zero-sum rhetoric suggests the presence of nationalism. Contrastingly, discourses opposing retaliatory tariffs frequently draw on personal experiences of the Chinese economy to convey pessimism about livelihood prospects in China. These discourses are comparatively less nationalistic, exhibiting acknowledgment of separation between the self and the country. The study ultimately finds that expression of strong nationalism is positively correlated with the use of emotive, combative, and hyperbolic language. Less nationalistic discourse generally opposes retaliatory tariffs and ground their arguments in personal experiences of the Chinese economy. Overall, nationalistic discourse appears more prevalent than non-nationalistic discourse, suggesting that Chinese Nationalism remains pervasive in contemporary China.

Elizabeth Huber CC'26, Applied Mathematics, Astrophysics

Faculty Mentor(s) or Supervisor(s): James Bock
Title: SFB Power Spectrum Emulation: Understanding the structure of our universe with the spherical Fourier-Bessel basis

Abstract: The SFB power spectrum emulator is a spherical Fourier-Bessel (SFB) emulator which enables inference of cosmological parameters, motivated by SPHEREx's (Spectro-Photometer for the History of the

Universe, Epoch of Reionization and Ices Explorer) goal to constrain primordial non-Gaussianity and model time evolving dark energy. The emulator will intake real sky data, and use the SFB basis to produce a likelihood distribution of cosmological parameters. The emulator is a neural network which was trained on a wide sampling of cosmological parameters, used to generate Cartesian matter power spectra, then subsequently transformed to SFB power spectra with primordial non-Gaussianity, fNL, and bias parameter modeling. This software will provide a widely accessible rapidly iterable surrogate for classical Boltzmann solvers, and will provide increased accuracy in constraining cosmological parameters by enabling improved data isolation and mode cuts. Future applications include applying our SFB power spectrum emulator to eBOSS cosmological surveys, and applications to SPHEREx to forecast their sensitivity to dark energy parameters, namely w0 and wa.

Charles Ibitamuno GS'26, Applied Mathematics

Faculty Mentor(s) or Supervisor(s): Scott Wallace
Title: Machine Learning for Hour-Ahead Solar Radiation Prediction in Seattle, WA

Abstract: The Solar Radiation Prediction Model project conducted over the past two months focuses on forecasting solar radiation levels using machine learning and deep learning techniques. Accurate solar radiation prediction is critical for optimizing solar energy systems, improving weather forecasts, and enhancing renewable energy management. The project begins by collecting and preprocessing historical solar radiation data along with other relevant environmental variables such as temperature, humidity, and time indices. Using this prepared dataset, several predictive models have been implemented, including traditional machine learning algorithms and artificial neural networks (ANNs). The machine learning models, like ANNs, are designed to capture nonlinear relationships within the data. Input features are carefully constructed by incorporating lagged data points, such as previous hour and previous day readings, to improve the accuracy of the predictions. Standard evaluation metrics, including Root Mean Squared Error (RMSE) and Normalized RMSE (NRMSE), are employed to measure prediction performance and guide model tuning. Throughout the process, emphasis is placed on model training, validation, and hyperparameter optimization to achieve the best possible results. Overall, the project demonstrates the effective integration of domain knowledge, statistical methods, and advanced deep learning techniques to deliver reliable solar radiation forecasts that can support energy planning and renewable energy resource utilization.

Andre Ignoffo CC'28, African American Studies, Political Science

Faculty Mentor(s) or Supervisor(s): Nyle Fort
Title: The Freedom of Flight: Exploring the Tale of the Flying Africans

Abstract: The fantastic story of Flying Africans, originating from the Igbo People of West Africa, has been passed down through generations and integrated into African American culture, life, and artistic expression. The naming of "Flying Africans" stems from the 1803 slave revolt at Igbo Landing off the coast of the St. Simon's Islands. Enslaved peoples rebelled against their captors on the Schooner York, a slave ship, by jumping overboard, choosing death over lifelong enslavement. In this account, it is believed that once they leapt, they were seen flying back to Africa, reclaiming both physical and spiritual freedom. From this act of rebellion, the story of Flying Africans was born, inspiring generations of African Americans to resist systemic oppression. The relationship between death and flight, symbolic of freedom, became integral to this story's adaptation into cultural life. Common slave funeral rites such as the "ring shout" symbolized a return home through music, dance, and chanting, guiding spirits to their ancestors. Premature Black death is central to the story's political meaning. Enslaved peoples were not only fleeing violence and mortality but also "social death." Orlando Patterson describes this as when "the slave had no socially recognized existence outside of his master." Severed genealogies, systemic violence, and perpetual surveillance sought to reduce enslaved peoples to instruments of capitalism. However, through storytelling and life-affirming practices, the tale has inspired Black literature, music, and art, from Ralph Ellison to Kendrick Lamar. Whether fact or fiction, the Flying Africans endure as a beacon of hope and political critique, testifying to the humanity, resilience, and pride of enslaved Africans and their descendants.

Lesley Iyamu CC'27, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Ishmail J. Abdus-Saboor
Title: Chronic Restraint Stress Impairs Fear Extinction Recall and Elevates Microglial (Iba1) and Neuronal (c-Fos) Activation in the Lumbar Spinal Cord of C57BL/6J Male Mice

Abstract: Fear and stress are deeply interwoven psychological processes regulated by distributed brain networks. Chronic stress, in particular, plays an important role in disrupting normal fear processing and extinction learning—

the ability to suppress previously learned fear responses—which has had profound implications for stress-related psychiatric conditions such as PTSD. While much of this research has focused on brain circuits, relatively little is known about the role of the spinal cord in fear regulation. Emerging evidence suggests that spinal microglia and neurons respond dynamically to stress and pain signals, yet their contribution to fear learning and memory processes like fear extinction remains poorly understood. In this study, we investigated whether chronic stress alters microglial and neuronal activation in the lumbar spinal cord during fear extinction recall in C57BL/6J male mice. We hypothesized that using the chronic restraint stress model would impair extinction recall, and that this behavioral change would be accompanied by elevated microglial and neuronal activity markers in the spinal cord. We found that stress-primed, fear-conditioned mice compared to fear-conditioned-only mice show desensitization to freezing and chronic stress activates both microglia and neurons in the lumbar spinal cord. Our findings demonstrate how chronic stress impairs fear extinction recall and contributes to the lumbar spinal cord's involvement with defensive (stress and fear) responses. This study offers a window to broaden current models that are beyond brain circuits, highlighting the spinal cord as an active player in adaptive emotional responses.

Emilia Jacome Justiniano CC'27, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): David Sulzer
Title: Investigating Epstein-Barr Virus Gene Expression in the Human Brain

Abstract: The Epstein-Barr virus, well known for causing infectious mononucleosis, is one of the most common human viruses, with over 90% of the population carrying the virus in a latent form. The virus has been linked to several malignancies, including Hodgkin lymphoma and Burkitt lymphoma. A recent study by Bjornevik et al. provided emerging evidence associating EBV infection to a significant increase in the risk of developing multiple sclerosis. Furthermore, current research indicates that infection with the herpesvirus family is a risk factor for dementia. Alzheimer's disease is the most prevalent cause of dementia, prompting questions about whether the Epstein-Barr virus might contribute to immune responses involved in neurodegenerative disorders such as Alzheimer's. This study looked at postmortem human brain tissue from both Alzheimer's patients and controls to detect and identify EBV in neuronal tissue. Male and female brain samples older than sixty years were analyzed. RNA in situ hybridization was used to identify EBV RNA in neurons, glial cells, and vascular cells. Across multiple experiments, the expression was consistently limited to latent transcripts of the virus. The viral signal was found in both neuronal and non-neuronal cells, with no significant difference between groups. The findings show that EBV was present in all aged brain samples, highlighting a widespread and previously unrecognized store of latent virus in the central nervous system. Ongoing work will further investigate the presence of EBV in younger individuals as well as the postmortem brain tissue from multiple sclerosis subjects.

Jaehoon Jung CC'26, Physics

Faculty Mentor(s) or Supervisor(s): James McIver
Title: n-Chip Terahertz Spectroscopy of Integer Quantum Hall Effects in van der Waals Heterostructures

Abstract: On-Chip Terahertz (THz) spectroscopy is an emerging tool for studying quantum phenomena of van der Waals (vdW) heterostructures that have resonances in the THz frequency range. When a 2D vdW such as graphene is subjected to a large magnetic field at low temperatures, the topology of its Fermi surface can be altered, forming Landau Levels in which electrons are confined to discrete cyclotron orbits. If a fractional or integer quasiparticle fills some number of Landau Levels, the system enters a topologically non-trivial insulating phase that supports chiral edge states. A notable example is the Fractional Quantum Hall Effect which is observable in Graphene and Twisted Bilayer MoTe2. By utilizing 2D Heterostructure Transfer, Atomic Force Microscopy (AFM), and Computer-Aided Design (CAD), we assembled a reference Graphite heterostructure and designed lithography patterns for its THz spectrometer circuit. Experimentally we expect the Hall Resistivity as a function of external magnetic field to be a series of rising plateaus, quantized by the filling factor of the Landau Levels. This summer, I focused on studying the integer quantum Hall effect by patterning on-chip THz spectrometers on van der Waals heterostructures. Detection of chiral edge states in THz-scale measurements of these devices would pave the way to similarly measuring and understanding more interesting phenomena.

Kay Kaiser GS'27, Earth Science

Faculty Mentor(s) or Supervisor(s): Benjamin Bostick
Title: Does My Drinking Water Have Uranium?: Using machine learning to predict uranium levels in regions of untested well water in New Jersey

Abstract: Chronic exposure to uranium in drinking water poses serious health risks, especially in rural areas where private wells are unregulated and rarely tested. However, predicting the spatial distribution of uranium contamination is difficult due to sparse sampling data. This study applied a machine learning framework to estimate groundwater uranium concentrations in untested wells using limited chemical and geological data, with a focus on developing scalable methods for underserved communities. Over 100,000 groundwater quality samples collected in New Jersey between 2003 and 2023 were compiled and aggregated to 2-mile grid cells. Each record included uranium, pH, iron, manganese, nitrate, and gross alpha activity. After cleaning and aggregation, random forest regression models were trained to identify key geochemical predictors of uranium. pH and gross alpha emerged as dominant variables, consistent with uranium's redox-sensitive mobility. Predictions of uranium concentrations were found to be higher along borders of geological regions throughout New Jersey. To address data scarcity, a two-step modeling approach was used: first, a geochemical model predicted uranium from more commonly measured variables; second, a spatial model was trained using geological and hydrological covariates to predict uranium concentrations without relying on chemical inputs. The resulting model generated a 2-mile resolution predictive map of uranium distribution across New Jersey. This map identifies areas of potential contamination risk and provides a transferable framework for other regions with limited data, including the Great Plains. These methods contribute to environmental justice efforts by identifying communities at elevated risk of uranium exposure where direct testing is unavailable.

Om Kar CC'26, Biology, Psychology

Faculty Mentor(s) or Supervisor(s): Harris Wang
Title: Engineering the Gut Microbiome: Next-Generation Tools from the Expanded MetaEdit Platform

Abstract: Microbial communities play fundamental roles in human health and environmental ecosystems, yet many species remain unculturable, limiting our ability to manipulate them for therapeutic and biotechnological applications. To overcome this challenge, we developed Metagenomic Editing (MetaEdit), a system that uses CRISPR-associated transposases delivered by a conjugative vector to enable precise, programmable, and stable genetic modifications within complex microbiomes. MetaEdit facilitates targeted genome integration of large DNA payloads with high efficiency, expanding the genetic toolbox for microbiome engineering. In a mouse model, we demonstrated its utility by stably integrating a gain-of-function inulin polysaccharide utilization locus into gut-associated Bacteroides species. The engineered microbes exhibited tunable engraftment under dietary fiber selection. To further demonstrate MetaEdit's versatility in editing diverse microbiomes, we extended our experiments to soil-derived microbial communities. We observed successful conjugative delivery of an antibiotic resistance and green fluorescent protein dual reporter into native soil bacteria. In ongoing work, we are also applying conjugation-based strategies to investigate how antibiotic resistance pathways influence the effects of chemotherapies in the gut microbiome. By cloning inert GFP payloads into resistance loci of Bacteroides and assaying their influence on drug response, we aim to identify microbial resistance pathways most relevant to chemotherapy resilience. To improve efficiency in this setting, we are developing optimized plasmid constructs that overexpress TolCRs to enhance conjugation. Our findings establish MetaEdit as a powerful and adaptable platform for in vivo microbiome engineering. Future work will focus on broadening target specificity and optimizing vectors to enhance efficiency and applicability across diverse microbiomes.

Eden Katz SEAS'26, Mechanical Engineering

Faculty Mentor(s) or Supervisor(s): Kristin Myers
Title: Computational Model of Shear Wave Elastography in the Cervix to Assess Premature Cervical Softening

Abstract: Preterm birth (PTB), defined as delivery before 37 weeks of gestation, is a leading cause of neonatal mortality and morbidity worldwide. About 80% of PTB cases occur without any clinical indications, known as spontaneous preterm (sPTB). The current clinical gold standard for assessing risk of sPTB, a short cervical length during the second trimester, has low predictive accuracy. Premature cervical softening is a promising metric for predicting sPTB, and shear wave elastography (SWE) is a minimally invasive ultrasound imaging technique used to measure tissue stiffness. However, its measurements are highly variable due to the cervix's complex microstructure and mechanical properties and changes throughout pregnancy. In this study, computational finite element (FE) simulations were used to investigate how cervical tissue properties influence shear wave propagation. Different material models were developed using the FE software FEBio to represent the microstructure and mechanical behavior of the cervix, consisting of different collagen fiber structures, tissue anisotropy, and changes in gestational status. To improve the accuracy of the model, a cylindrical geometry with stratified collagen layers was created, and the dynamic interactions between interstitial fluid and porous cervical tissue were incorporated. The finite element

simulations demonstrated that collagen fiber dispersion, tissue anisotropy, and gestational status influence shear wave speed, highlighting how these properties can affect cervical softness measurements obtained from SWE. Understanding these effects can help guide the design of ultrasound probes optimized for detecting sPTB. In addition, this allows for development of a standard shear wave speed in the cervix to assess sPTB risk.

Louis Ke SEAS'27, Computer Science

Faculty Mentor(s) or Supervisor(s): Tony Dear
Title: Fast Finetuning and Conversion of Pre-trained RoBERTa to Linformer

Abstract: The introduction of the transformer architecture reshaped the landscape of natural language processing models. However, the main drawback of this architecture is its quadratic time and space complexity with respect to the input sequence length. Recent developments in alleviating this cost focus on exploring linear-complexity variations of the transformer, such as the Linformer. While such variations greatly reduce the time and space cost of training large models, the pre-training expense still remains a barrier for the average user, who generally only has access to a single GPU. Current methods to obtain a Linformer model, other than pre-training one from scratch, involve converting a pre-trained model into a Linformer model through guided learning during the fine tuning process. This process requires fine tuning two models, a teacher model as well as a student Linformer model, in order to guide the desired Linformer model towards high-quality representations. We aim to explore the improvement in the time required to perform this model conversion process by eliminating the necessity of fine tuning a teacher model. We show that this is empirically possible, with results demonstrating an alternative conversion method during the fine tuning process for the Linformer architecture that achieves comparable performance to current methods in less time.

Andrew Kelly CC'26, Chemistry

Faculty Mentor(s) or Supervisor(s): Jonathan Owen
Title: Surface Functionalization of Mn-doped CdS/ZnS Photocatalysts for Improved Stability and Performance

Abstract: Designing efficient photocatalysts is crucial for facilitating a variety of organic transformations, and quantum dots (QDs) have recently emerged as powerful and cost effective alternatives to precious metal-based photocatalysts. QDs have many properties that make them desirable for photocatalysis, but one of the most commonly utilized QDs, CdS, faces issues of degradation under photocatalytic conditions. Depositing a protective ZnS shell doped with Mn2+ has been a successful approach to improving the stability and activity of CdS QDs, but further optimization of the QD surface conditions has not been extensively explored. Thus, this study aimed to synthesize Mn-doped CdS/ZnS QDs capped with 3-phosphonopropionate (PPA) or tributylammonium formate (TBAF) to determine ligand effects on photocatalytic activity, hypothesizing that these ligands would help to stabilize the QDs and improve their reactivity. Hot injection and SILAR methods were utilized to synthesize the QDs, and ligand exchanges were conducted to transfer the QDs into DMF with PPA/TBAF ligands. QDs were irradiated at 427 nm over a period of 18 hours in DMF with a catalyst loading of .0005 mol % and a variety of substrates to determine photocatalytic activity. TBAF-capped QDs were found to be more powerful photocatalysts, obtaining higher yields than the PPA-capped QDs for harder to reduce substrates. PPA-capped QDs were able to be effectively recycled though, whereas TBAF-capped QDs demonstrated degradation post-irradiation. These findings demonstrate the advantages of PPA and TBAF as effective ligands for improving the stability and performance of QD photocatalysts, facilitating easier and more efficient organic synthesis.

Bradley Kelton CC'28, Earth Science, Physics

Faculty Mentor(s) or Supervisor(s): Jerry McManus
Title: Coulometric Calibration for Iberian Margin Sediment Cores

Abstract: The burial and preservation of calcite in benthic sediments are poorly understood, yet they are crucial for interpreting late pleistocene biological and climate processes. Coulometry is a time intensive procedure that is the standard method for measurement of calcite concentration. X-Ray Fluorescence, or XRF, is a more efficient process which measures counts of calcium atoms, but is not a sufficient proxy for the concentration of carbonate due to the presence of other calcium-bearing minerals. This project aims to standardize a process for converting calcium counts produced by XRF to calculate calcite concentration without the need for Coulometric measurement in Ibereian Margin sediment cores, specifically from IODP Expedition 397 sites U1586 and U1587 . A non-linear least squares regression showed strong complementary exponential fits between XRF and coulometry generated data for both sites. Because of the contrasting depths of each drill site, the fact that both fits follow the same trend suggests that further data could elucidate a more general method for producing calcium carbonate data sets in North Atlantic sediment cores by adjusting for stratigraphic depth profiles. This procedure would greatly expedite the measurement of calcite in benthic

sediments which would then be useful in addressing the applicability of calcium carbonate as a biological productivity marker, assessing strain on the supply of dissolved marine calcite, and determining the cause of asynchronicity between calcite cycles in the world's major ocean basins.

Shilpa Kesavan CC’26, Mathematics

Faculty Mentor(s) or Supervisor(s): Marco Castronovo
Title: Morava K-theory of Toric Varieties

Abstract: Cohomology is a powerful tool that helps mathematicians study complex topological spaces through simpler algebraic structures. Morava K-theory, constructed in the 1970s, is a type of generalized cohomology theory that has received renewed interest in recent years. Although the Morava K-theories of some topological spaces have been studied and computed, they remain unknown for most classes of spaces. This project seeks to investigate the Morava K-theory of toric varieties, a special class of algebraic varieties known for their high degree of symmetry and rich combinatorial structure. While the K-theory of toric varieties has been studied and well described (Cortinas et al., 2007), their Morava K-theory has yet to be computed. Due to the symmetries exhibited by toric varieties, it is hypothesized that the resulting algebraic structures will be fairly elegant. By computing and analyzing these structures, this project aims to contribute to the development of new insights in algebraic topology and homotopy theory.

Caden Ketchman CC’27, Medical Humanities

Faculty Mentor(s) or Supervisor(s): Richard Mann
Title: Inactivation of Individual Interneurons in Drosophila Leading to Changes in Walking Behavior

Abstract: This project explored how the brain controls walking by studying fruit flies, a widely used model in neuroscience. The researcher focused on a specific circuit of neurons that helps regulate movement. Using genetic tools, individual neurons within this circuit were selectively turned off to test their role in walking. The flies were then observed in a controlled arena, where their steps, speed, and overall walking patterns were carefully monitored and compared to those of flies with intact circuits.
The results revealed that most neurons in the circuit could be turned off without major consequences, because other neurons were able to compensate and maintain normal walking behavior. However, some neurons proved to be essential. When these key neurons were inactivated, the flies displayed clear changes in how they walked, such as slower speeds or altered step patterns. This finding suggests that not all neurons in the walking circuit are interchangeable. While many provide a form of backup for each other, certain neurons lack redundancy, meaning that the loss of even one can noticeably disrupt behavior.
By identifying which neurons are indispensable for walking, this research helps build a clearer picture of how the brain organizes movement. Beyond fruit flies, the findings may contribute to a deeper understanding of motor control and neurological conditions in more complex animals, including humans.

Zoya Khan CC’27, Cognitive Science, Computer Science

Faculty Mentor(s) or Supervisor(s): Attila Losonczy
Title: Ongoing Plasticity in Hippocampal CA1 Representations During Learning

Abstract: How does the brain store stable memories while remaining plastic to new experiences? The gradual stabilization of experience-dependent representations in hippocampal circuits is thought to underlie episodic memory, supported by inputs from upstream regions. Yet the dynamics of individual place cell formation and persistence in the hippocampus during learning – and how they are shaped by broader networks – remains incompletely understood. We used two-photon calcium imaging to longitudinally track CA1 pyramidal neurons as mice learned to navigate a virtual reality environment across five days. To investigate network influence, we recorded both VGLUT1-expressing cells and a sparse population of conditional knockout (VG-) cells lacking glutamate release, functionally disconnecting them from the broader entorhinal-hippocampal system. In both groups, place fields tuned to specific locations emerged rapidly in early sessions, with a progressive increase in the number of active place cells. However, very few maintained stable fields across sessions, indicating high turnover. To further probe dynamics, we assessed signatures of behavioral timescale synaptic plasticity (BTSP), but only a small fraction of neurons exhibited BTSP-like induction, suggesting alternate plasticity mechanisms may dominate this context. Notably, VG- neurons were preferentially recruited on the first day, but showed reduced participation and persistence on subsequent days. While initial encoding was robust in both populations, early recruitment in VG- cells suggests that disconnection from the wider entorhinal-hippocampal circuit biases these cells towards a burst of initial encoding without early stabilization. Together, these results provide some insight into how memory representations evolve across days of learning, at the single-cell level.

Elaheh Khazi CC’27, History, Middle Eastern, South Asian, and African Studies

Faculty Mentor(s) or Supervisor(s): Sibghatullah Ghaznawi, Ali Karjoo-Ravary
Title: Reclaiming Our Narrative: Redefining the Story of the Afghan American Diaspora

Abstract: The recent targeting of migrants in the US exemplifies the widespread misinformation and misunderstanding of migrant communities. This research project addresses the lack of awareness about Afghan migrants and the broader Afghan American diaspora by concentrating on the stories of Afghan refugees and immigrants. The study is focused on the Afghan communities in New York City and California’s Bay Area, which represent two of the most concentrated Afghan populations in the US. Despite the formation of vibrant communities across the US, Afghan American histories remain largely absent from academic discourse and are frequently distorted by biased and vilifying media portrayals, especially since the War on Terror. This study counters these misunderstandings by documenting the reality of Afghan migrant experiences. The project uses oral history methodology, archival records, and statistical analysis of migration trends to construct a greater understanding of the major migration waves out of Afghanistan to the United States following the Soviet-Afghan War of 1979, a proxy conflict of the Cold War. In addition to recovering untold narratives, the study maps the geographic concentration of Afghan Americans, including community centers, businesses, and cultural organizations, in Queens, NYC, and Fremont, California. This project’s findings emphasize not only the trauma experienced by Afghan Americans but most importantly the resilience expressed throughout the community, especially as second- and third-generation Afghan Americans build community spaces. By bringing to light Afghan voices that are often forgotten, this project contributes to reclaiming the narrative of the Afghan American diaspora.

Justin Kiel GS’27, Political Science

Faculty Mentor(s) or Supervisor(s): Jeffrey Lax
Title: Selective Enforcement: Prosecutorial Discretion and the Non-Enforcement of Political Misconduct in Indiana

Abstract: This research investigates the uneven enforcement of Indiana’s election and local government administration laws, focusing on how prosecutorial discretion shapes accountability for political misconduct. Indiana statutes in Titles 3 and 36 establish penalties for actions ranging from campaign finance violations to failures in government recordkeeping. These laws exist to safeguard the public’s trust in governmental institutions, yet they are rarely enforced against elected or political officials. Using statewide court filing data from 2016 to 2024, this study analyzed 1,258 charges involving election or government administration statutes. Notably, more than 80 percent of chargeable offenses applicable to elected and political officials had no recorded prosecutions. Of the few election-related cases filed, none proceeded to trial. In contrast, minor offenses committed by the general public, such as the misuse of 911 calls, were charged over a thousand times during the same period. The findings reveal that statutes intended to hold officials accountable function largely as symbolic measures without consistent enforcement. Indiana’s decentralized prosecutorial system, combined with limited oversight and potential political incentives, contributes to this selective application of the law. These findings suggest that reforms are needed to ensure that misconduct by elected officials is prosecuted with the same consistency as offenses committed by the public.

Thaddaeus Kiker CC’27, Astrophysics

Faculty Mentor(s) or Supervisor(s): Carlos Paz-Soldan
Title: From Conformal Manual Winding to Autonomous Carriages: A Scalable Workflow for HTS Deposition on Nonplanar Stellarator Coils

Abstract: Stellarator magnet construction requires precise placement of high-temperature superconducting (HTS) tape onto complex, nonplanar coil geometries that include mixed concavity, tight curvature, and varying torsion. These geometries play a key role in achieving good plasma confinement but also create significant challenges for REBCO-class HTS materials, which are highly sensitive to strain from hard-way bending and out-of-plane deformation. To address these issues, we developed a three-stage HTS winding workflow as part of the Columbia Stellarator Experiment. The first stage introduces a hybrid manual method that uses a gimbal-mounted coil orientation system and conformal retention carriages to maintain tangential alignment and apply local normal force in concave regions. This method reduces strain during winding and improves placement fidelity. Experiments on test magnets confirmed a 33 percent reduction in winding time compared to baseline clamp-based approaches. In the second stage, we developed the Autowinder platform, which uses a rack-and-pinion carriage system to traverse arbitrary three-dimensional coil paths with no external sensing or multi-axis positioning. We embedded a conformal rack directly into the coil

flange using a parallel transport frame and meshed it with geared carriages to achieve deterministic and repeatable motion. Tests on printed coil prototypes with a single deep concavity showed stable multi-revolution winding. In the final stage, we extended the system with Autowinder II by adding distributed multi-cart control, servo-driven pressure actuation, motorized HTS payout, and synchronized solder deposition. The updated platform uses battery-powered carts with wireless communication to remove tethering and enable geometry-independent operation. This complete system moves HTS winding from a manual and repetitive task to an integrated and automatable process that supports the scalable fabrication of next-generation stellarator magnets.

Richelle Kim CC’27, Biochemistry

Faculty Mentor(s) or Supervisor(s): Robert Reid
Title: Disruption of XRS2 in Saccharomyces cerevisiae and its Impact on Homologous Recombination Outcomes following a DNA Double-Stranded Break

Abstract: Double-strand breaks (DSBs) in DNA pose a threat to genome integrity across all organisms. Luckily, in diploid cells, the broken chromosome can utilize its homolog as the repair template in a process known as homologous recombination. The MRX (Mre11-Rad50-Xrs2) complex tethers broken DNA ends during homology search, facilitating their movement through the nucleus and their consequent interaction with the correct homolog. Despite the known role of MRX in end tethering, its role in shaping the distribution of resulting homologous repair outcomes remains unclear. Here, she shows that deletion of XRS2 in Saccharomyces cerevisiae shifts the balance from predominantly error-free and coordinated DSB repair toward error-prone outcomes characterized by loss of heterozygosity (LOH). Using fluorescent markers and a site-specific endonuclease which induced DSBs on Chromosome V, she observed that the XRS2-deleted diploid colony dataset was dominated by outcomes in which one or more markers were lost or made homozygous, reflecting the bias toward LOH-generating repair pathways. Thus, the XRS2-deleted vs. wild-type comparison underscores the role of the Xrs2 protein, and equivalently the MRX complex, in promoting high-fidelity homologous recombination. These insights highlight the conserved role of Xrs2 and its human ortholog Nbs1 in safeguarding the genome of eukaryotes against the mutagenic consequences of DSBs.

Min Jae Kim CC’26, Chemical Physics

Faculty Mentor(s) or Supervisor(s): Norman Tubman
Title: Surrogate Optimization for the Variational Quantum Eigensolver

Abstract: The Variational Quantum Eigensolver (VQE) is a quantum algorithm popular for potential applications in quantum chemistry-type calculations. More specifically, VQEs calculate an upper bound for molecular systems’ ground state energies. This allows one to compute the optimal molecular structures (bond lengths and angles with the lowest energy)—a procedure called geometry optimization. Quantum algorithms such as VQE receive much interest as quantum computers have been predicted to be more efficient than their classical counterparts for quantum calculations. More specifically, the number of required qubits and quantum operations would scale less with system size. Amongst quantum algorithms, VQE shows promise through its resilience to quantum noise. However, VQEs still require further adjunct optimization procedures for applications in geometry optimization. Surrogate optimization is a noise-resistant procedure developed for conventional quantum chemistry algorithms such as Quantum Monte Carlo (QMC). QMC suffers from random noise, much like the VQE. Surrogate optimization mitigates the influence of noise in this optimization by considering an approximate Hessian for the studied system’s ground state energy. This approximate Hessian is computed via a computationally cheaper surrogate theory. Then, the QMC energy can be minimized more efficiently by appropriately applying the approximate Hessian information. This method has been applied to a simulated VQE for a water molecule. Moving forward, a noise model will be applied to the simulated VQE such that it imitates a real quantum computer.This will test the practical viability of surrogate optimization for real VQEs.

Justin Kim CC’28, History

Faculty Mentor(s) or Supervisor(s): Adam Tooze
Title: The State of Exception

Abstract: This project examines the theory of the State of Exception - that, in times of crisis, legal norms are suspended and the power of the executive grows beyond its original constitutional limits. In particular, it scrutinises Giorgio Agamben's argument that this State of Exception has become the rule, rather than the exception, in modern democracies. This project primarily aims to be a comprehensive legal and historical inquiry of Agamben’s thesis, which draws on earlier thinkers such as Carl Schmitt, a German jurist, who originally developed this idea of a ‘State of Exception’ as a means to justify Nazi rule. This project will also briefly examine Agamben’s philosophical influences, such as Hannah Arendt, Michel Foucault, and Walter Benjamin, in order to further contextualise his arguments. By exploring the intersection

of law, history, and social marginalisation, this project aims to re-examine the role of law in the state, and how it can be used both as a tool of governance and oppression.

Julia Kirby CC’27, Archaeology, Physics

Faculty Mentor(s) or Supervisor(s): Carlos Paz-Soldan
Title: Automation and Operation of Pellets at Columbia

Abstract: Pellets at Columbia (PAC) is a test stand for the injection of cryogenic pellets into plasmas. Cryogenic pellet injection has been used experimentally in tokamaks, devices that magnetically confine plasma for fusion-related purposes. Pellet injection has been shown to mitigate disruptions, fuel the plasma, and pace edge localized modes. PAC uses a cold head to freeze gas into a pellet which is then injected via copper punch. The pellet enters a vacuum chamber where it is ablated by a well-characterized electron beam, simulating the injection of pellets into a plasma. PAC offers multiple diagnostic tools such as resonant microwave cavities to measure the mass of the pellets before and after ablation and a fast camera to calculate the angle of deflection due to the rocket effect from ablation mass loss. Further, PAC offers the ability to create pellets out of mixed gases using Hydrogen, Deuterium, Neon, and Argon. Ultimately, PAC will calculate the rocket effect and the ablation rates as a function of pellet species and size. Ablation scaling laws will be produced as a function of electron current. Recent work includes manufacturing and installing a dump plate for the current released by the electron beam and creating a cone to catch the pellet after it is ablated by the electron beam. A PID system was also implemented to automatically control the temperature and pressure inside the injection chamber where the pellet is created.

Nicholas Koch CC’27, Physics

Faculty Mentor(s) or Supervisor(s): Kazuhiro Fujita
Title: Development of Cryogenic Radio Frequency Amplification Circuit for Shot Noise Scanning Tunneling Microscopy

Abstract: Scanning Tunneling Microscopy, STM, uses an atomically sharp metal tip to measure the current of electrons as they quantum-mechanically tunnel through a junction, or a vacuum, to a sample. Thus, STM naturally provides a new technical platform for detecting shot noise, the noise generated as electrons tunnel through tip-vacuum-sample junctions. By measuring such noise, one can visualize a charge of electrons in space that reflects an intrinsic property of quantum materials at an atomic level. This imaging provides insight into various material properties, such as unconventional/topological superconductors, Quantum Hall systems, and so on. However, this noise is very small, so it must be amplified and isolated from all other interference. This study developed a radio frequency amplification circuit using an array of high-pass and low-pass filters to achieve voltage amplification and frequency filtering, thereby isolating shot noise. This circuit is initially simulated using online software to analyze amplification, voltage, and current throughout the circuit. Then, it was assembled using indium soldering. After assembly, the device is tested using a lock-in amplifier, demonstrating its effectiveness and ability to amplify voltage at a specific frequency. From simulations, the circuit design exhibited a voltage amplification gain of approximately 36 times at a frequency of approximately 2 MHz. Within testing, this circuit exhibited an amplification gain of 15 times at a frequency ranging from 2 to 3 MHz (tested at room temperature). These results support promising amplification of future measurements to map shot noise across samples utilizing STM.

Chinmay Kumar CC’27, Chemistry, Medical Humanities

Faculty Mentor(s) or Supervisor(s): Steven P. Menez
Title: Biomarker Associations with Histopathologic Patterns of Acute Tubular Injury in Human Kidney Biopsies

Abstract: Acute tubular injury (ATI) is the most common subtype of acute kidney injury (AKI) in hospitalized patients. While kidney biopsy remains the diagnostic gold standard, its invasiveness and bleeding risk limit routine use. This study investigated the association between urinary biomarkers and histologic features of ATI. Data were analyzed from 219 participants in the Novel Approaches in the Investigation of Kidney Disease (NAIKiD) Study at Johns Hopkins, all of whom underwent native kidney biopsy between September 2020 and February 2023. Urine samples collected at biopsy were assayed for epidermal growth factor (EGF), monocyte chemoattractant protein-1 (MCP-1), kidney injury molecule-1 (KIM-1), neutrophil gelatinase-associated lipocalin (NGAL), tumor necrosis factor-alpha (TNF-α), chitinase-3-like protein 1 (YKL-40), and interleukin-18 (IL-18). Clinical pathology reports were reviewed to identify histologic descriptors of ATI and tubulointerstitial inflammation. Sixteen tubular injury descriptors were identified, including tubular cell sloughing (15.1%), epithelial flattening/simplification (34.2%), tubular dilatation (17.4%), and apical blebbing (36.1%), along with five descriptors of inflammation. Creatinine-indexed biomarker levels were significantly elevated or lowered in patients with tubular sloughing, epithelial flattening, and tubulointerstitial

inflammation. In adjusted models, each doubling of urinary KIM-1:Cr and MCP-1:Cr was associated with increased odds of tubular cell sloughing (adjusted odds ratios 1.71 and 1.67, respectively; $p < 0.05$). Urinary biomarkers show strong associations with specific histologic features of ATI, suggesting their potential utility as non-invasive indicators of ATI presence and severity. These findings support further evaluation of urinary biomarkers to improve noninvasive diagnostic strategies.

Tara Lago CC’27, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Rohani Cena-Navarro
Title: Development of a DeepLabCut and SimBA Model for Toluene-induced addiction and CUMS-induced Depressive-like behavior in Rats

Abstract: Adolescence is a period of heightened vulnerability to environmental stressors. In the Philippines, half of first-time drug users are adolescents with toluene being one of the most abused drugs. In addition to increased risk of addiction, there is also an increase in stressors that contribute to depression. Thus, the Behavioral Neuroscience Lab’s goal is two-pronged: to study the basic mechanisms behind toluene-induced addiction and to treat depressive-like behavior induced by Chronic Unpredictable Mild Stress (CUMS) through a rat animal model. Yet outside of ANY-maze and handscoring methods, the lab has no robust digital workflow to study toluene and CUMS. To enhance the reproducibility and efficiency of the lab’s research, I developed the first machine learning DeepLabCut (DLC) and SimBA models in the Philippines using the recorded forced swim test (FST) and novel object recognition (NOR) tasks. When comparing the performance of ANY-maze with my machine learning models, I found that ANY-maze significantly measured higher times, suggesting that ANY-maze overestimates the presence of target behaviors. On reanalysis of published NOR data with my model, I found that the times recorded by SimBA and hand scoring were not significantly different from each other, suggesting that the DLC and SimBA workflow is consistent with established handscoring methods. Thus, DLC and SimBA might be the better tools for measuring behavior time than ANY-maze. Overall, this work contributed to the emerging neuroscience field in the Philippines by developing and validating DLC and SimBA models to analyze behavior impacted by addiction and depression.

Celeste Lamadrid SEAS’26, Mechanical Engineering

Faculty Mentor(s) or Supervisor(s): Steven Meitner
Title: Effect of Terminal Straight Sections on Cryogenic Pellet Dispersion in Curved Guidetubes

Abstract: Injection of solid cryogenic pellets comprised of hydrogenic isotopes is the primary method of fueling a burning fusion plasma. They are also utilized for plasma edge stability control through edge localized mode (ELM) pacing. In the design of pellet guidetube systems, the dispersion angle of pellets exiting the tube is a critical parameter. It is key to ensuring that the pellets are reliably captured by the downstream guidetube as they travel across gaps in the system. Current dispersion angle experiments have been conducted using straight guidetubes and provide a dispersion allowance of 2 degrees. In this experiment, we detail the dispersion of hydrogen (H_2) pellets through a guidetube geometry based on a curved ITER guidetube section. The tube has a 0.6 m radius bend through an angle of 15 degrees. A length of straight guidetube terminating this bend was varied from 0.15 m to 0.61 m to determine its collimating effect. Pellets were created using a continuous single screw extruder developed by Oak Ridge National Laboratory (ORNL), and pellet speed was varied within the range of 139 m/s to 1089 m/s. We found that the pellet dispersion formed a spiral in which the radius increased with decreasing length of the terminating straight guidetube, and that a minimum length of 0.30 m for the terminating guidetube was required for the dispersion angle to remain within 3 degrees. The experimental results provide design criteria to improve reliability in the pellet delivery system to fusion plasmas.

Owen Lear CC’26, Astrophysics, Mathematics

Faculty Mentor(s) or Supervisor(s): Sebastian Mizera
Title: Hawking Radiation of Black Holes from Semiclassical Scattering Amplitudes

Abstract: Black holes serve as one of the most fundamental objects to test our understanding of gravity and quantum field theory. Following Stephen Hawking’s 1974 discovery that black holes emit radiation, there have been countless methods presented to compute the spectrum of this Hawking radiation. Our research focuses on extending recent results of Aoude et al. (2024) in which the Hawking spectrum was obtained by methods of semiclassical quantum field theory. From this new perspective, we can use the familiar and powerful tools of quantum field theory — in particular, the analytic continuation of energy to complex values. First, to compute the scattering amplitude that contains information about the Hawking temperature, we consider a particle experiencing changes in momentum as it

passes a black hole. Recognizing that the analytic structure of this amplitude is what produces the Hawking temperature of a black hole, we focus on identifying the temperature as early in the calculation as possible, in order to understand the characteristics of the Schwarzschild metric that produce an ambient temperature. Additionally, we pursue extensions of the approach of Aoude et al. to arbitrary dimension and the case of a rotating black hole. We solve the case of arbitrary dimension exactly, with matching results to the standard theoretical predictions. The success of this approach in arbitrary dimension provides motivation for future work — in particular to understand how adding spin or further modifications to the spacetime may enrich the analytic structure of the scattering amplitude.

Emily Lee GS’28, Biochemistry

Faculty Mentor(s) or Supervisor(s): Marta Olah
Title: Investigating the population structure of microglia in the aged African American brain

Abstract: African Americans (AA) are disproportionately affected by Alzheimer’s disease (AD) compared to non-Hispanic whites (NHW), yet their representation in research on AD remains limited. Microglia, the brain’s resident innate immune cells, are critical to maintaining homeostasis and responding to neurodegeneration in AD. How genetic, epigenetic, and environmental factors influence these cells in aged AAs with and without AD is poorly understood. To establish the population structure of microglia in aged AAs, we performed single-cell RNA sequencing (scRNA-seq) on microglia isolated from the dorsolateral prefrontal cortex and anterior watershed deep white matter of eight AA donors from the MARS cohort. Unbiased clustering of the scRNA-seq dataset revealed nine microglial subsets. The identity of these subsets aligned with earlier described microglia subsets in aged NHW. Intriguingly, the protective microglia subset (previously named Cluster 7) was significantly depleted in the current dataset, in line with our hypothesis. Analysis of surface protein expression showed drastically reduced abundance of microglia bearing the CD74high phenotype (characteristic of the protective microglia subset) in aged AAs. We confirmed that we captured the protective microglia subset using its CD74high expression profile in situ using immunohistochemistry and immunofluorescence. Our findings chart the landscape of microglial heterogeneity in aged AAs. We established an automated image analysis pipeline to explore this subset’s relationship to neuropathological hallmarks of brain aging and AD in situ. By elucidating microglial phenotypes associated with AD and their variability across populations, this study will provide a foundation for precision medicine strategies targeting neuroimmune mechanisms in diverse populations.

Ethan Lee SEAS’28, Materials Science

Faculty Mentor(s) or Supervisor(s): Derek Ning, Vanessa Li, Clark Hung, Ke Cheng
Title: Synovial Fibroblast Extracellular Vesicles: A Pathway Connecting Osteoarthritis to Adverse Cardiac Outcomes

Abstract: Growing evidence suggests that cardiovascular disease (CVD) and knee osteoarthritis, two of the most prevalent conditions worldwide, are closely correlated (1, 2). Although they share risk factors such as age, obesity, smoking, and diabetes, the mechanisms linking cardiac and joint pathology remain unclear (1). Specifically, myocardial infarction (MI) accounts for a third of CVD cases and is crucially modulated by cardiac fibroblasts (CFs) which contribute to the inflammatory and repair response and the formation of fibrotic tissue that can lead to further adverse cardiac remodeling. Similarly, fibroblast-like synoviocytes (FLS) in the knee regulate immune infiltration and joint inflammation in osteoarthritis. A potential inter-organ link involves communication via extracellular vesicles (EVs), lipid bilayer–enclosed carriers of stress-specific particles that mediate cell communication (3). Because EVs exhibit cell-type specific tropism, the fibroblast-fibroblast crosstalk mediated by EVs between the knee and the heart is particularly interesting, given the central role FLS and CFs play in their respective diseases. In this study, we hypothesize that EVs released by inflamed FLS in osteoarthritis contribute to the inflammatory response of CFs as well as cardiomyocytes. First, a co-culture experiment between inflammatory FLS and CFs was performed to establish potential linkage. EVs were then isolated from FLS treated with IL-1b and control conditions, and then were used to treat CFs and cardiomyocytes. Through these studies, the inflammatory effect that FLS-derived EVs can have upon CFs indicates a potential linkage between osteoarthritis and heart disease.

Matthew Lee CC’27, Biochemistry

Faculty Mentor(s) or Supervisor(s): Dana Pe'er
Title: Transcriptional Regulators of Plasticity in Colorectal Cancer Metastasis

Abstract: Metastatic colorectal cancer (CRC) is responsible for the majority of disease mortality compared to primary CRC tumors, but the mechanisms that enable their increased lethality remain poorly understood. Previous work has shown that metastatic CRC tumors enter a stem-cell like oncofetal state

followed by expansion into either an intestinal canonical state or rarely, a neuroendocrine noncanonical state. Understanding cell state transitions along this continuous canonical-noncanonical axis would provide insight into how subpopulations of metastatic CRC tumors co-opt transcriptional programs to become increasingly more dangerous. We analyzed multiome scRNA-seq and scATAC-seq from two MSKCC patient metastatic liver CRC samples and found both shared and patient-specific cascades of transcription factors that specify canonical and noncanonical cell states, including CDX2, BACH2, and PROX1. We then used an autoencoder network, scDoRI, to identify peaks with coordinated changes in chromatin accessibility that orchestrate the activation and repression of inferred gene regulatory networks during cell state transitions. Using in silico ChIP-seq, we found a set of transcription factors that bind these dynamically accessible peaks and individually possess dual activator and repressor functions across distinct peak sets. Further analysis of one of these transcription factors, FOXP1, showed that it shifts from an activator when present in a canonical cell state to a repressor during a noncanonical cell state while maintaining relatively high expression. Taken together, transcription factors with context-dependent function are correlated with canonical-noncanonical transitions during metastatic CRC and may enable metastatic tumors to gain additional plasticity.

Laura Ann Lesley CC’26, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Laura Duvall
Title: Effects of photoperiod on survival, egg laying, and post-biting locomotor activity in Ae. albopictus and Ae. aegypti

Abstract: I am an undergraduate in the Duvall lab investigating the effects of photoperiod on the behavior and egg-laying patterns of Ae. albopictus and Ae. aegypti mosquitoes. Mosquitoes bite and feed on the blood of mammalian hosts in order to obtain the proteins necessary to produce their eggs. A female may produce multiple clutches of eggs in her lifetime and therefore bite multiple hosts, enabling mosquitoes to spread disease-causing pathogens among humans. Ae. albopictus have the ability to produce embryonically arrested, or diapause, eggs that lay dormant in the winter months, when adult populations die off, and hatch when favorable conditions return in the Spring, allowing populations to be renewed perennially. Therefore, Ae. albopictus are actively expanding their range into temperate zones which widens their ability to spread disease-causing pathogens. To better understand the biological mechanisms behind the production of diapause egg production and Ae. albopictus’ ability to successfully survive in temperate zones, I am investigating comparisons between these two mosquito species in three facets: survival differences in various photoperiods at low temperature, oviposition (egg-laying behavior) and egg hatch rate in short photoperiod and low temperature, and locomotor activity of both bloodfed and non-bloodfed animals in low temperature in various photoperiod conditions. I have found that Ae. albopictus appears to have a longer oviposition timeline than Ae. aegypti at short daylength and low temperature, and the hatch rates of Ae. albopictus eggs decrease over time. Additionally, findings indicated that the two species demonstrate differences in post-biting locomotor activity in both short and long daylength.

Norzin Lhadon CC’26, Psychology

Faculty Mentor(s) or Supervisor(s): Umrao Monani
Title: Investigating transduction of AAV Gene Therapy Vectors in Non-Human Primates for Glut1DS

Abstract: Glucose transporter type 1 deficiency syndrome (Glut1DS) is a rare genetic disorder caused by mutations in the SLC2A1 gene, which impair the brain’s access to glucose. This condition often appears early in life and can lead to seizures, developmental delay, and cognitive disabilities. Currently, there is no cure for Glut1DS. Adeno-associated viruses (AAVs) have emerged as promising gene therapy delivery methods for treating genetic disorders. To evaluate this approach, non-human primates (NHPs) were injected with one of two Green Fluorescent Protein (GFP)-tagged AAVs, AAV-SK or AAV-MT, while control NHPs were injected with phosphate-buffered saline (PBS). To detect the presence of viral DNA and protein, tissues including the heart, spleen, gastrocnemius, triceps, spinal cord, kidney, and liver, as well as brain regions such as the thalamus, hippocampus, cerebellum, and cortex were analyzed. PCR and western blotting were used to measure and compare expression patterns across tissues. While viral DNA was detected across tissues, GFP protein expression was limited to specific tissues, suggesting that further experiments and optimization are needed to clarify the efficacy of these AAVs. Identifying the distribution of GFP-tagged AAVs in these tissues can provide a step toward modifying these vectors to deliver a functional Glut1 gene in future studies. Such findings lay the groundwork for clinical trials in patients with Glut1DS and broaden the understanding of viral vectors in gene therapy for neurological and genetic disorders.

Andrew Li CC’27, Astronomy

Faculty Mentor(s) or Supervisor(s): Jane Huang

Title: Inside the Castle of Dust: Peering inside the vertically extended disk of SU Aurigae with ALMA

Abstract: The young T Tauri star SU Aurigae is known to possess a complex system of possibly misaligned protoplanetary disks, consisting of a well-studied inner disk, as well as a more poorly characterized outer disk. Here, I present an analysis of newly acquired images of the dusty outer disk around SU Aurigae, taken with the ALMA radio telescope. Taken in the 1.3-millimeter dust continuum bandpass, these images reveal a compact outer disk which outshines the emission of inner disk previously known from infrared observations. I present two preliminary radiative transfer models of the disk structure, suggesting that the disk is roughly divided into three different dust zones, and also discuss apparent asymmetries within the disk emission, which suggest that the disk is significantly vertically extended.

Antonio Li CC'28, Computer Science

Faculty Mentor(s) or Supervisor(s): Lydia Chilton
Title: Programming as Dialogue: LLMs and Designers in Collaborative 3D Modeling

Abstract: Recent advances in artificial intelligence have expanded generative models from text and images into three-dimensional design. Yet most 3D generation efforts rely on diffusion methods that output imprecise point clouds or meshes, making results difficult to edit and poorly suited for integration with professional modeling software. This paper proposes a programming-centered alternative: positioning large language models (LLMs) as generators of executable code in familiar languages such as Python, which is then used to construct 3D models within established 3D design softwares like Rhinoceros 3D. By making code the foundational representation, the framework ensures outputs remain parametric, editable, and compatible with design workflows, while also enabling gradual improvement of generative quality through iterative prompting. Crucially, this approach introduces bi-directionality: programming code becomes the shared language through which both human designers and AI can collaborate. Designers can refine a model either by editing the code directly or by manipulating the 3D model in the design environment, with those changes translated back into code. The LLM can then generate, interpret, and modify that same code, creating a continuous feedback loop of co-design. Multi-cycle prompting and iterative sampling further enhance this process by balancing creativity with geometric clarity and encoding constraints for scale, form, and program-specific requirements. Results show that code-based generation produces models more robust to iteration and customization than diffusion-only methods, opening pathways for interactive, collaborative AI–human 3D modeling. Challenges remain in scaling spatial reasoning and reducing geometric overlaps in complex prompts, but the study highlights the promise of aligning 3D generation with the strengths of LLM programming, effectively allowing 3D modeling to "piggyback" on advances in code generation.

Christine Li SEAS'26, Computer Science

Faculty Mentor(s) or Supervisor(s): Lia Yeh
Title: A qutrit [[6, 2, 2]] quantum error-correcting code with a transversal binary AND gate

Abstract: Quantum computation and error correction in higher dimensional systems offer a promising route to more efficient and robust codes and circuits, compared to qubits. In this work, we present a novel qutrit [[6, 2, 2]] quantum error correcting code with a transversal implementation of the binary AND gate. The key insight in our approach is that we can interpret a symmetric T-depth one circuit decomposition — composed of a CX circuit, T and T dagger gates, followed by the CX circuit in reverse — as a distance 1 CSS code. We thereafter increase the code distance by augmenting the code circuit with additional stabilizers while preserving the "built-in" transversal logical binary AND. As a result, we can leverage qutrit Clifford+T circuit synthesis to combine the advantages of quantum error correction and qudits, and moreover protect against leakage errors to higher levels.

Grace Li CC'28, Computer Science, Mathematics

Faculty Mentor(s) or Supervisor(s): Mike Wilkins
Title: MPI4AI: RCCL Integration

Abstract: Modern supercomputers help researchers solve some of the world's toughest problems, ranging from climate modeling to AI training. To do this work efficiently, thousands of computers must work together and share information. Message Passing Interface (MPI) is a communication standard that makes this possible. But as AI and scientific computing increasingly rely on GPUs, traditional MPI methods are falling behind. They often move data between the CPU and GPU in ways that slow things down. New GPU libraries like NVIDIA's NCCL and AMD's RCCL are much faster but don't follow MPI standards and are harder to use with existing software.
Our project solves this by bringing AMD's RCCL into MPICH, a widely used MPI implementation. This means existing programs can now communicate

directly between GPUs without major rewrites and still comply with MPI standards. Even better, our system automatically picks the faster path (CPU or GPU) based on the size of the data. In tests, it ran some communication tasks over 60 times faster than before. This work supports the Department of Energy's mission to advance scientific discovery with cutting-edge computing. It helps ensure that scientists using MPI can fully benefit from modern GPU hardware without changing their software.

Leo Li CC'27, Biology

Faculty Mentor(s) or Supervisor(s): Fei Fang
Title: Primary Cilia in Gli1-Lineage Cells Regulate Enthesis Development and Homeostasis

Abstract: Rotator cuff injuries affect more than 17 million individuals in the US, with injury and degradation of the tendon-bone attachment, enthesis, being a main contributor. As we age, our enthesis weakens due to degradation overtime and potential bone spur growth. Current treatments for rotator cuff injury cannot fully regenerate tissue structure and function, accompanied with scar formation at the enthesis and limited shoulder mobility. The primary cilium is recognized as an important signaling hub to regulate mechano-sensitivity and hedgehog pathway in enthesis. The exact means of this regulation is suspected to be through hedgehog signaling (Hh), where Gli1 is a key transcription factor in this pathway. Gli1 expressing progenitor cells have been found to be crucial for enthesis formation, repair, and homeostasis. Using in vivo mice models, the role of primary cilia in enthesis development, homeostasis and its underlying mechanisms utilizing its regulation of the Hh signaling pathway were investigated. Conditional deletion of primary cilia in Gli1-lineage cells resulted in impaired cell differentiation and reduced fibrocartilage throughout development, while deletion of primary cilia in mature mice impaired cell differentiation specifically in the unmineralized enthesis region. Furthermore, treatment with a smoothened agonist failed to fully rescue the effects of primary cilia deletion, overall confirming the importance of primary cilia in enthesis development and homeostasis. In the future, RNA sequencing of the cilia-deleted enthesis will be performed to hopefully identify the exact molecular mechanisms behind ciliary function, Hh signaling and uncovering potential gene targets for therapeutic intervention.

Margaret Li GS'26, Art History

Faculty Mentor(s) or Supervisor(s): Kent Minturn
Title: Meyer Schapiro and Fernand Leger: A Dialogue Between Medieval and Modern Art

Abstract: As a professor at Columbia University and one of the most influential American art historians, Meyer Schapiro made lasting contributions to the discipline. His specialties ranged from early Christian art to contemporary art. He justified abstract art as not a "mere ornament" because it is closely tied to society. In 1935, he introduced Fernand Leger to the medieval illustrated manuscript Commentary on the Apocalypse (Morgan Beatus) and discussed the Romanesque abbey of Vezelay with him, both of which may have inspired Leger's work. Previous scholarship has noted the presence of Beatus's motifs in Leger's work of the 1940s; this research examines how that influence extended into his 1950s paintings and explores other medieval traditions he drew upon, such as Vezelay. This study consults Meyer Shapiro's papers and research notes from 1919 to 2006 in the Rare Book & Manuscript Library at Columbia University, alongside other art historical scholarship. By conducting a formal analysis of Leger's Les grands plongeurs noirs (1944) and La grande parade (1954), illustrations in Morgan Beatus, and the tympanum reliefs of Vezelay's narthex portal, this research demonstrates how Leger was inspired by these medieval sources—especially in composition, color, layout, and figure's depiction—for his paintings of both the 1940s and 1950s. Undoubtedly, Meyer Schapiro fostered a dialogue between old art and the present, encouraging modern artists like Leger to draw inspiration from medieval art while, in turn, bringing contemporary voices into the tradition.

Sophie Li CC'28, Applied Mathematics, Computer Science

Faculty Mentor(s) or Supervisor(s): Guy Van den Broeck
Title: Tractable Representations and Training of Categorical Mixture of All Trees (MoAT) Models

Abstract: The Mixture of All Trees (MoAT) model compactly represents a mixture of all spanning tree graphical models, leveraging Kirchhoff's Matrix–Tree theorem to encode exponentially many structures in polynomial size (Selvam, Zhang, and Van den Broeck, 2023). This allows for tractable likelihood computation, despite the hardness of exact marginal inference. However, this original formulation was restricted to binary variables. This project extends MoAT to categorical domains by developing parameterizations, using iterative proportional fitting (IPFP) as a projection method to enforce consistency of pairwise joint parameters with marginals. This approach enables optimization via projected gradient descent. In

practice, categorical MoATs are evaluated on flattened ImageNet patches, where the model attains competitive likelihoods relative to strong baselines. Further, taking the benchmark datasets of the original MoAT paper, categorical variables are constructed by grouping bits together (e.g., base-4), and mutual information and entropy-based heuristics are used to guide the choice of groupings. This strategy aims to improve likelihood performance over the original binary MoAT baseline while maintaining tractable training. Preliminary experiments indicate that grouping improves likelihood especially when the data contains concentrated, higher-order dependencies that are not captured by pairwise interactions. Further exploration could extend these methods to continuous domains through latent-variable formulations and copula-based mixtures. This suggests a path toward boosting expressive power while retaining MoAT's tractability.

Eileen Lin SEAS'28, Mechanical Engineering

Faculty Mentor(s) or Supervisor(s): Sunil K. Agrawal
Title: Postural Support through C.A.S.T: A Cable-Driven System for Trunk Stabilization in Seated SCI Patients

Abstract: Complete paraplegia and incomplete tetraplegia affect over 210,000 individuals in the United States, with a significant portion experiencing impaired trunk control that limits independence and can lead to secondary complications. Existing solutions have limited degrees of freedom in movement, can be expensive to build and maintain, and lack versatility and deploy-ability in daily living activities. To address these limitations, the Cable-Assisted Stabilizing Torso (C.A.S.T.) system was created. It is a wearable, motor-driven solution designed to provide adaptive torso support for individuals with spinal cord injuries. C.A.S.T. utilizes a dual-cable mechanism mounted on wheelchair back canes and a custom-fitted vest to facilitate dynamic stabilization in flexion, extension, and lateral bending. When calculating the feasibility of the system, the torso was modeled as a bidirectional inverted pendulum on a universal joint with two degrees of freedom. We evaluated the system's torque-balancing capabilities and demonstrated 91% coverage of posture space in real-world movement data. The vest features adjustable straps, nylon fabric, and modular cable attachments to ensure an ergonomic fit and effective force transmission. An easy-to-access button allows users to toggle between neutral, free, and stabilized states, which supports both mobile and stationary postures. Preliminary feasibility results suggest that C.A.S.T. can significantly enhance bimanual reach and torso stability, thus allowing for increased autonomy in daily living activities. This research contributes to the development of scalable, user-centered rehabilitation technologies that promote functional independence for individuals with spinal cord injuries.

Joanna Lin CC'26, Evolutionary Biology of the Human Species

Faculty Mentor(s) or Supervisor(s): Nandan Nerurkar
Title: How Mechanical Signals Shape the Gut: Linking YAP Signaling to Gut Loop Morphology

Abstract: Gut looping is a conserved developmental process, in which the vertebrate intestine organizes into a compact series of loops, driven by differential growth between the gut tube and mesentery, a membranous tissue anchoring the gut tube to the dorsal body wall. Gut looping is well characterized in chicken embryos, where the gut tube forms a series of homogeneous, regularly shaped loops between embryonic day 8 (E8) and 16 (E16). While broadly conserved, deviations in this process can reveal how developmental shifts generate morphological variation between species. The American Pekin duck (Anas platyrhynchos domesticus) presents one such case, forming an elongated central loop, known as the Meckel's loop, while surrounded by "chick-like", common loops. Previous ATAC-seq analysis revealed enrichment of TEAD motifs in Meckel's loop, implicating the Hippo signaling pathway in its development. TEAD functions downstream of Hippo signaling and requires the co-activator YAP, a known mechanotransducer, to drive gene expression. This study aims to test whether constitutive activation of YAP is sufficient to alter gut looping morphology and potentially mimic the elongated Meckel's loop phenotype seen in ducks. Using an RCAS retroviral system, we injected and electroporated YAP5SA and GFP (control) into the coelemic cavity of day 3 chick embryos (E3). Embryos were sacrificed at days 8, 12, and 14. YAP-electroporated embryos showed variable phenotypes, including looser and distended gut tubes. Immunostaining confirmed viral infection, nuclear YAP enrichment, and regions of proliferation using PHH3 stainings. Despite phenotypic variability in YAP5SA electroporated samples, our preliminary results suggest that constitutive activation of YAP induces localized disruptions of gut looping, offering insight into the mechanisms that contribute to species-specific intestinal morphology.

Bridget Liu CC'28, Biochemistry, Computer Science

Faculty Mentor(s) or Supervisor(s): Mohammed AlQuraishi

Title: Deciphering the Biophysical Determinants of Peptide-Binding Domain Specificity Using Machine Learning

Abstract: Protein–protein interactions mediated by peptide-binding domains (PBDs) and short linear motifs (SLiMs) play a key role in regulating cellular signaling pathways. Malfunctions in these pathways are implicated in a range of diseases, including cancer and neurological disorders. While high-throughput experimental methods have uncovered binding preferences within individual PBD families, they fall short of revealing the broader molecular principles that govern binding specificity across all PBD families found in the human proteome. In this work, we apply mechanistic interpretability techniques to protein language models to investigate the biophysical determinants of SLiM recognition across 24 human PBD families. Using sparse autoencoders, we extract interpretable features from protein representations and identify four distinct classes of specificity determinants: (i) domain-specific, (ii) family-specific, (iii) features shared across two families, and (iv) features shared across all families. Our findings take the first steps towards revealing common recognition strategies and diverse specificity mechanisms that underlie PBD–SLiM interactions, offering a unified framework for understanding how signaling proteins achieve both selectivity and promiscuity. Our work highlights the potential of interpretable machine learning to uncover mechanistic insights into protein function and could serve as a future foundation for rationally engineering signaling interactions or diagnosing the effects of disease-associated mutations.

Claire Liu CC’28, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Emilie Grasset
Title: Investigating the impact of Crohn’s disease microbiota on mesenteric adipocytes and intestinal inflammation

Abstract: Crohn’s disease (CD) is a chronic inflammatory bowel syndrome (IBD) characterized by inflammation, bleeding, and ulceration of the terminal ileum. One of its key hallmarks that remains poorly understood is known as creeping fat, the presence of abnormal mesenteric adipose tissue (MAT) wrapping around the inflamed intestines. Within creeping fat, a consistent finding across CD patients is a reduction in adipocyte cell size. We hypothesized that bacterial translocation from the terminal ileum into the MAT promotes increased lipolysis, leading to adipocyte size shrinkage due to excessive fatty acid release. In this study, germfree (GF) mice were orally gavaged with microbiota taken from patient donors, two CD patients (CD_BSD2780_0875 and CD_J1100826) and one healthy donor (HD_1001262B). Adipocyte imaging and western blot analyses suggested that the CD_BSD2780_0875 patient microbiota increased lipolysis and corresponded with visibly smaller adipocytes. We further hypothesized that the increased release of fatty acids promotes B cell class-switching toward inflammatory IgG-secreting plasma cells. Previous work from the Grasset lab demonstrated that the CD_J1100826 patient microbiota drove serological signs of inflammation. In our experiment, we used IL-10-/- mice, a model for intestinal inflammation, and confirmed that this CD microbiota induced inflammatory changes in mouse intestinal organs. By better understanding the mechanisms through which CD patient microbiotas drive disease phenotypes, we can apply these principles to other IBDs and future therapeutic strategies.

Sally Liu SEAS’26, Computer Science

Faculty Mentor(s) or Supervisor(s): Nuttida Rungratsameetaweemana
Title: SpikeRNN: Biologically Constrained Models of Cognitive Computation

Abstract: Understanding complex cognition requires mathematical models that capture both the large-scale interactions of brain networks and the discrete spikes through which neurons communicate. Traditional artificial neural networks often simplify this process by averaging activity into continuous “rates,” which makes them easier to train but strips away the spiking detail that is central to real brain function. Spiking recurrent neural networks (RNNs) preserve this biological realism but remain challenging to construct and analyze. Building on the framework of Kim et al. (PNAS, 2019), which introduced a one-to-one mapping from rate-based recurrent neural networks (RNNs) to spiking leaky integrate-and-fire (LIF) networks, we developed spikeRNN, a modular PyTorch framework for training and evaluating functional spiking RNNs. Our framework introduces a systematic workflow: First, we train rate-based RNNs under biological constraints such as Dale’s principle, which requires that each neuron is either purely excitatory or inhibitory in its outputs. Next, we map them to spiking networks using an optimized scaling procedure. Finally, we evaluate them on diverse cognitive tasks, including Go-NoGo, XOR, and context-dependent integration. Crucially, spikeRNN moves beyond replication by introducing extensible APIs for customizing architectures, configurations, and tasks, as well as new utilities for probing network robustness. These include in silico lesion experiments, where recurrent connections are selectively ablated in the model to assess functional resilience, and comparative studies of excitatory–inhibitory balance. Together, these advances make spikeRNN a practical and

extensible research tool that lowers barriers to modeling while enabling systematic exploration of biologically constrained recurrent dynamics.

Josh Lohmolder GS'28, Astrophysics

Faculty Mentor(s) or Supervisor(s): Savin
Title: Dissociative Recombination Rate Coefficient Fits for Modeling the Evolution of Interstellar Clouds

Abstract: The evolution of interstellar clouds can be studied using molecular ions that trace their key physical properties. Accurately modeling these environments requires a detailed understanding of the chemical processes that form and destroy these species. Dissociative recombination (DR) is a key destruction mechanism for molecular cations such as OH^+, CH^+, and CF^+. Data for DR are often in the form of cross sections as a function of collision energy. However, for modeling, researchers need rate coefficients as a function of the kinetic temperature, i.e., the cross section times the relative electron-ion collision velocity integrated over the velocity distribution of the plasma. To this end, we have calculated kinetic temperature rate coefficients for DR of rotationally cold OH+, CH+, and CF+ over a temperature range of 1-10,000 K by averaging theoretical cross sections over a Maxwell-Boltzmann velocity distribution. The DR cross sections were obtain from previous theoretical studies2. The resulting theoretical rate coefficients were then fit with equations typically used for chemical modeling. This also provided parameters that can be compared with data from previous experiments al work3,4 at the Cryogenic Storage Ring. Here, we discuss our theoretical results, compare to experimental results, and discuss planned future theoretical work.

Amy Lu SEAS'27, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Tal Danino
Title: NanoPro - Engineered Probiotics for Targeted Cancer Nanotherapy

Abstract: Most solid tumors are so molecularly similar to healthy tissue that they are inaccessible even to modern targeted therapeutics. To address this issue, the Danino Lab has previously engineered bacteria for intratumoral release of ProTag, an orthogonal antigen (GFP) which anchors to tumor matrix via a heparin-binding domain. To aid in establishing NanoPro—a system for intratumoral therapeutic delivery via ProTag(i.e. GFP)-targeted nanoscale vectors—we modified a murine colorectal adenocarcinoma cell line, MC-38, via lentiviral transduction to mimic ProTag labeled cells through expression of membrane-bound GFP, generating ProMimic-38. Both monoclonal and polyclonal ProMimic-38 strains were obtained through fluorescence-assisted cell sorting. We then injected these strains subcutaneously into C57BL/6 mice, and engraftment (tumor volume) was monitored until eighteen days post injection, at which point the tumors were excised and dissociated for analysis. At the endpoint, all ProMimic tumors displayed macro- and microscopic GFP signal. Additionally, ProMimic-38 cells—but not parental MC-38 cells—were found to be selectively transduced by an anti-GFP lentiviral vector. Together, these findings represent a proof-of-principle for the NanoPro system and establish a novel tumor model. For future work, experiments will be conducted to evaluate the specificity and efficiency of NanoPro vectors in vivo, providing an opportunity to gauge whether GFP-targeting prevents these vectors from accumulating in non-target tissues.

Isabella Lu SEAS'28, Computer Science

Faculty Mentor(s) or Supervisor(s): Linnia Hawkins
Title: Investigating Snowpack-Shrub Interactions in the Arctic Tundra using Machine Learning and Process Models

Abstract: The Community Land Model (CLM), the land component of the Community Earth System Model (CESM), simulates key terrestrial processes including carbon cycling, photosynthesis, and snowpack dynamics. While CLM is an indispensable tool for advancing ecosystem process understanding, it is computationally expensive to run. We developed machine learning emulators that efficiently approximate CLM outputs for plant, snow, and soil variables across different parameter settings, enabling efficient exploration of model behavior and hypothesis testing. In this study, we apply these emulators to investigate feedbacks between snowpack, shrub growth, and soil conditions in Arctic Tundra ecosystems. After running sensitivity analysis with our emulators, we identified that increased snowpack suppresses plant growth, while lower snowpack supports plant growth, suggesting a negative feedback loop. To validate these findings we performed CLM simulations with fixed plant parameters and varying snowpack parameters, and results confirmed our emulator predictions, strengthening evidence for a negative snow-vegetation feedback loop in CLM. Our results suggest that CLM does not capture the positive feedback loop between snowpack and plant growth observed in Arctic ecosystems, and we further investigate the mechanisms governing the feedback between snowpack and vegetation. This work demonstrates how machine learning and process models can be used in tandem to improve understanding of ecosystem processes.

Keanna Luo SEAS’27, Chemical Engineering

Faculty Mentor(s) or Supervisor(s): Oleg Gang
Title: Multilayer DNA Origami Lattices

Abstract: Natural materials like seashells form complex structures through precisely controlled growth. Reproducing this type of growth synthetically is difficult, especially at the nanoscale. In this project, we explored a way to create complex DNA nanostructures by regulating their nucleation and growth. We used octahedral DNA origami frameworks as modular building blocks. Directional growth was programmed through carefully designed sticky DNA ends, while internal sticky ends allowed selective trapping of gold nanoparticles (AuNPs). By sequentially adding monomers, we grew lattices layer by layer, alternating between gold-filled and empty DNA origami shells. The temperature at which the origami were incubated was essential in creating highly ordered, crystalline structures. By controlling the temperature, we were able to suppress unwanted homogeneous nucleation, while encouraging heterogeneous nucleation and growth. The crystal structure and morphology of the multilayer lattices were studied using optical microscopy and small angle X-ray scattering (SAXS). Overall, this project shows a design for a programmable nanostructure with potential applications in drug delivery and soft robotics. It highlights how bottom-up designs using DNA technology can take inspiration from nature to create multifunctional synthetic materials.

Taylor Lynch CC’27, Political Science, Sociology

Faculty Mentor(s) or Supervisor(s): Mario Small
Title: The Impact of Polarization on Community Vitality in New York City Neighborhoods

Abstract: A recent surge in 21st century scholarship has studied growing trends of division caused by political polarization, but little has been devoted to analyzing its impact on community connectivity at the neighborhood level. As numerous community-based organizations have formed to combat the dismantling of neighborly relationships based on ideological differences, this research aims to look beyond the surface level community building initiatives instituted by municipal governments, NGOs, and scholars and instead turns to individuals. How are neighborhood dynamics being shaped by polarization? How is community vitality and individuals' sense of communal belonging changing? Which communities are the most susceptible to quality of life impacts from polarization and which are the most resilient? To answer these questions, this mixed methods study determines the relationship between shifts in voting behavior, community vitality (determined through voter participation, incarceration and youth engagement), poverty rate, community demographics and geographic characteristics of the 198 Neighborhood Tabulation Areas (NTAs) in New York City. The research finds a direct and statistically significant negative correlation between community vitality and shifts in voting behavior, supporting the hypothesis that increases in polarization are directly related with decreases in neighborhood connectivity. Four sample neighborhoods – representing the four observable levels of community vitality – are further explored based on their history, community organizations, and resident testimony to create individual neighborhood profiles. This mixed method approach contributes to the growing body of literature on polarization and offers insights into future research on mitigating losses of community vitality caused by polarization on the neighborhood level.

Maya Madajewicz CC’28, Earth Science

Faculty Mentor(s) or Supervisor(s): Christine McCarthy
Title: Experimental study of acoustic wave amplitude change during normal stress perturbations in ice

Abstract: Identifying early indications of earthquakes requires knowledge of how faults move under different constraints. The use of acoustics is a novel method to probe for essential fault characteristics including contact strength and stress at fault interfaces. Both manually transmitted and passively collected acoustics can be indicative of friction, contact strength, and stress changes at the fault boundary. Melt and deformation at fault interfaces are poorly understood factors of acoustic and seismic attenuation and are difficult to study in small scale laboratory experiments. We investigate how melt and deformation impact the manually transmitted acoustic emissions we use to characterize fault interfaces. Ice serves as a good proxy to study how rock deforms on a large scale in the field and how that deformation affects acoustic signals. We conducted experiments probing the contact evolution and acoustic transmissivity of active fault boundaries using ice-on-ice and glass-on-ice stress experiment techniques in a cryogenic servo-controlled biaxial apparatus. We found that, consistent with previous observations, manually transmitted acoustic emission amplitudes are positively correlated with changes in normal stress at fault boundaries when melt is not present. However, as melt and deformation increase, acoustic emission amplitudes become significantly less correlated with normal stress and can demonstrate a negative correlation with normal stress. We also found that as temperature

increased and the fault exhibited more melt and deformation, friction coefficients decreased. Our results suggest that although acoustics cannot be used as a direct proxy for normal stress at regions of high stress and temperature, changing acoustic amplitudes can be used to analyze factors at the fault contact that influence slip likelihood.

Karolina Majewska SEAS'26, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Sheng-Han Kuo
Title: The Cerebellum Demonstrates Event Related Potentials Linked to Attention and Conflict Processing

Abstract: The Stroop effect is a classic paradigm used to investigate selective attention and conflict processing by presenting interference between language and color information. When measured with electroencephalography (EEG), this effect reliably elicits event-related potentials (ERPs) in the prefrontal cortex, including the N2 and P3 responses to conflict, and error-related negativity (ERN) following incorrect responses. Research suggests that attention and conflict resolution during the Stroop effect involves a communication pathway between the prefrontal cortex and the cerebellum, known as the fronto-cerebellar loop. However, cerebellar ERPs during the Stroop task have not been examined using EEG. Therefore, this study investigated whether the cerebellum shows similar or distinct ERPs compared to the prefrontal cortex during Stroop task performance. A novel cerebellar-cortical EEG technique was used to record fifteen healthy controls performing two variations of a computerized Stroop task. EEG data were time-locked to stimulus onset for N2 and P3 analysis, and to error responses The Stroop effect is a classic paradigm used to investigate selective attention and conflict processing by presenting interference between language and color information. When measured with electroencephalography (EEG), this effect reliably elicits event-related potentials (ERPs) in the prefrontal cortex, including the N2 and P3 responses to conflict, and error-related negativity (ERN) following incorrect responses. Research suggests that attention and conflict resolution during the Stroop effect involves a communication pathway between the prefrontal cortex and the cerebellum, known as the fronto-cerebellar loop. However, cerebellar ERPs during the Stroop task have not been examined using EEG. Therefore, this study investigated whether the cerebellum shows similar or distinct ERPs compared to the prefrontal cortex during Stroop task performance. A novel cerebellar-cortical EEG technique was used to record fifteen healthy controls performing two variations of a computerized Stroop task. EEG data were time-locked to stimulus onset for N2 and P3 analysis, and to error responses to measure ERN. Results revealed cerebellar ERPs corresponding to N2, P3, and the ERN, localized over electrodes positioned over cerebellar posterior regions. These ERPs were detected in both cortical and cerebellar electrodes, however, the cerebellar electrodes showed variations in amplitude and latency. These findings indicate that cerebellar EEG can be used to detect attention and conflict processing in the cerebellum during the Stroop effect, supporting the involvement of the fronto-cerebellar loop. By establishing reliable cerebellar ERPs, this study paves the way for further investigation on how cerebellar activity is modulated by task manipulations or altered in cerebellar dysfunction.

Inès Mamodaly CC'27, Biology

Faculty Mentor(s) or Supervisor(s): James Manely
Title: Exploring how cancer mutations in splicing factor genes remodel the leukemia proteome

Abstract: RNA splicing edits gene messages by removing introns and joining exons, a task carried out by the spliceosome. Recurrent mutations in spliceosome genes (SF3B1, SRSF2, U2AF1) in leukemia can misdirect this process. SF3B1 often promotes cryptic upstream 3′ splice sites triggering nonsense-mediated decay (NMD) and lowering protein output. This study aimed to (1) map how these mutations reshape the proteome of K562 leukemia cells and (2) build a splicing-informed proteogenomic reference to reveal mutant-specific protein fragments that standard databases miss. Mutant and wild-type cells were profiled by LC-MS with western blot validation and integrated RNA-seq. At 1% false discovery rate, the team identified 8,422 proteins and saw broad, coordinated shifts in mutant cells. RNAs known to be mis-spliced were matched by reduced protein output, consistent with nonsense-mediated decay. They also detected isoform-specific differences and peptides present only in mutant cells, along with proteins that changed without direct mis-splicing, evidence of compensatory pathways. In sum, splicing-factor mutations reshape the leukemia proteome via both direct (mis-splicing → NMD) and indirect responses. A splicing-informed proteogenomic workflow closes database blind spots and uncovers mutant-specific isoforms and neoepitopes, pointing to testable vulnerabilities and paving the way for more targeted diagnostics and therapies.

Nate Maretzki CC'28, Data Science

Faculty Mentor(s) or Supervisor(s): Aleksandar Obradovic
Title: SingleViper: A Novel Protein-Based Cell-Type Annotation Workflow

Abstract: Accurate annotation of cell types from single-cell RNA sequencing (scRNA-seq) data remains challenging under conditions of low transcript depth and high technical noise. Traditional annotation pipelines rely on transcript abundance, which poorly reflects cellular state when genes are sparsely expressed. To address this, we present SingleViper, a workflow that integrates transcriptional regulatory network inference and protein activity estimation to classify cell types based on regulatory dynamics instead of simply gene expression alone. Using ARACNe3, we infer a regulon from reference expression matrices, which is then used with the VIPER algorithm to transform query and reference gene expression data into protein activity scores. The resulting activity matrices serves as inputs for supervised classification using either SingleR or a custom machine learning classifier. To test the pipeline's robustness, we downsample the query dataset and benchmark purity, accuracy, and per-class of SingleViper against standard gene-expression–based annotation methods. We hypothesize that VIPER-based annotations will consistently outperform baseline methods in low-depth settings. These results would suggest that protein activity signatures offer a stable, biologically informed representation for robust single-cell cell type classification going forward, which could serve as an alternative to gene-expression–based classification.

Priyanka Mathews CC'27, Biochemistry

Faculty Mentor(s) or Supervisor(s): Filippo Mancia
Title: Development of a Purification Protocol for Plasmodium falciparum's Drug/Metabolite Transporter 1

Abstract: The increasing prevalence of drug-resistance in the deadliest malaria parasite Plasmodium falciparum has become one of the biggest threats to controlling the disease in endemic countries, where malaria remains a leading cause of death. Resistance of P. falciparum to the standard antimalarial quinine has been shown to be linked to mutations of the drug/metabolite transporter 1 (DMT1), making this protein a promising drug target for combination therapies. This project aims to solve the structure of DMT1 through cryo-electron microscopy (cryo-EM) as a first step towards rational drug-design. Preliminary cryo-EM screening revealed that DMT1 is too small to resolve without a fiducial marker. To overcome this limitation, a new DMT1 construct was engineered with tags to enable binding of a novel ALFA nanobody–Fab (NabFab) complex. The new construct was then cloned before being incorporated into a virus for ease of protein expression. Following cloning, the construct was incorporated into a viral system to facilitate high-yield protein expression. Current efforts focus on optimizing expression and purification conditions, after which cryo-EM micrographs of the DMT1–NabFab complex will be collected to solve the transporter's structure.

Danielle Maydan SEAS'26, Computer Science

Faculty Mentor(s) or Supervisor(s): Dana Pe'er
Title: Encoding single-cell chromatin landscapes as probability distributions with optimal transport

Abstract: Single-cell ATAC-seq maps chromatin accessibility at a single-cell resolution, identifying regions of open chromatin. In the context of bone marrow hematopoiesis, multiome data, which pairs chromatin accessibility with gene expression levels, holds great promise for elucidating the epigenetic regulation of cell fate decisions and transcriptional dynamics. Conventional ATAC-seq pipelines primarily focus on analyzing chromatin accessibility by detecting accessible genomic regions, often overlooking the rich information encoded in the actual shapes of accessibility peaks. These peak shapes can offer a more nuanced understanding of chromatin dynamics, revealing insights into transcription factor (TF) binding loci, RNA polymerase recruitment, and broader transcriptional machinery interactions. Here, we analyzed subtle patterns in single-cell bone marrow data by modeling the distribution of ATAC-seq reads, which result from the unique pattern of enzymatic (Tn5 transposase) cutting of accessible DNA. Specifically, we generated histograms of Tn5 cutsites centered at transcription start sites (TSS) to investigate whether shape-based information regarding chromatin accessibility patterns can predict gene expression levels. To capture shape-based features in a lower-dimensional space, we trained an autoencoder that preserves differences between cutsite distributions by encouraging Euclidean distances in the latent space to approximate the histograms' pairwise Wasserstein distances, a measure from optimal transport theory well-suited for comparing distributions. We then performed linear regression on both the latent embeddings and the histogram features to predict gene expression. These analyses revealed that promoter shape may encode information regarding transcriptional levels, supporting the idea that accessibility pattern shapes carry regulatory signals lost in conventional ATAC-seq analysis pipelines.

Yuval Mazor GS'27, Psychology

Faculty Mentor(s) or Supervisor(s): Irving Weissman
Title: Tracking βIII-tubulin-Positive Neurons with Endogenous Membrane GFP

Abstract: Background: Three-dimensional cortical organoids derived from induced pluripotent stem cells (iPSCs) provide valuable models for studying neural development and calcium dynamics. However, visualizing neurons throughout thick organoid structures remains challenging due to limitations in viral transduction efficiency and tissue penetration. Objective: To develop a stable, endogenous neuronal reporter system that enables uniform labeling of neurons throughout 3D organoids without relying on repeated viral delivery. Methods: We compared neuronal labeling efficiency between 2D iPSC-derived cortical cultures and 3D organoids using AAV9-CaMK2a-GFP and AAV9-syn-gcamp6f viral vectors at Day 10. To address the limitations observed with viral approaches, we designed a CRISPR-mediated knock-in strategy targeting the TUBB3 gene (βIII-tubulin), an early pan-neuronal marker. The approach involved creating a C-terminal EGFP fusion construct with homology arms for precise genomic integration. Results: While AAV transfection was successful in 2D cortical cultures, 3D organoids showed only surface expression with poor viral penetration into inner tissue layers. This resulted in incomplete neuronal labeling throughout the organoid structure. Preliminary work on the knock-in approach included successful primer design for homology arm amplification and cloning of the IRES-GFP construct. Conclusions: Viral-based labeling approaches are insufficient for comprehensive neuronal visualization in thick 3D organoids. The development of a βIII-tubulin-EGFP knock-in cell line represents a promising alternative that could provide uniform, stable neuronal labeling throughout organoid structures. This endogenous reporter system would enable more accurate analysis of calcium dynamics and neural network activity in 3D cortical models, advancing our understanding of neural development and synaptic plasticity. Future Directions: Validation of the knock-in construct through sequencing, testing CRISPR efficiency in iPSCs, and establishment of a stable reporter line for characterizing neuronal labeling in organoids.

Ginnie McKnight GS’27, Political Science

Faculty Mentor(s) or Supervisor(s): Brandi Summers
Title: Art based research as a modal praxis in depicting and solving AI innovation disparities in spatial geography disspossession, energy depletion, and ethical data acquisition methodology.

Abstract: How can generative AI methodology be better innovation stewards in data acquisition, spatial global impact, human computer interaction, and epistemic dispossession? To enhance legibility of the interdisciplinary spanse of the aforementioned research question, an art research praxis was used to visually contextualized, and present the findings. The original research is conveyed via a hand drawn, oil painted art reasearch poster. The poster design was accepted into the Columbia University Data Science AI Summit 2025. Painting as a method of contextualizing the complex intersection of chipset regulatory compliance, and historical epistemic disparate impact, was a decided veer from convention. To enhance the legibility of interdisciplenary AI impacts, a two minute film was created to synthesize AI’s spatial impact on epistemically disspossessed environments, and the conspicuous energy and material e-waste of AI hardware. Summer 2025 research offered me the opportunity to become Informed on programming in Python for research methods, data extraction protocols for research, and LLM queries. This provided sentient details in methods of acquiring data, and building the LLM’s generative AI rely on. This quantitative research segue provided hands on experience with AI research beyond the scope of AI policy, implementation compliance, and global methods of AI Legal Compliance. As a result, using a controled design architecture prompt, with the smallest agentic generative utility of $3.33, an end to end web app was built. In using the most minimal AI generative model available, findings on the viability of generative AI architecture, and automation emerged. In keeping with the initial critique of the adverse impacts of AI governance in LLM data acquisition, this research created a methodology in data architecture for LLM data acquisition, and exposed the vulnerability of automation. The research asserts, a capacious need, for a more human steered input in AI innovation ecosystems.

Pedro Henrique Meerbaum GS’27, Comparative Literature and Society, Maia Zasler GS’27, Sustainable Development

Faculty Mentor(s) or Supervisor(s): Roy Mittelman
Title: Fragmented Memories: Exploring the Impact of Cultural Preservation and Revitalization Policies on the Moroccan Jewish Community

Abstract: This research examines how Moroccan governmental and grassroots efforts to preserve Jewish heritage sites influence tourism, diasporic engagement, cultural continuity, and the narrative construction of Jewish history in contemporary Morocco. The work is situated in the context of rising tourism rates world-wide as well as Morocco’s vested political and economic interest in attracting a greater number of visitors. 550,000 Moroccans are directly employed by the nation’s tourism sector, indicating that 15% of the active population relies on the industry. With the signing of the Abraham Accords in 2020 and the subsequent formalization of Moroccan-Israeli relations, there has been an increased number of diaspora Moroccan

Jews engaging in heritage tourism and hillulot. The preservation of sites relevant to the Moroccan Jewish community both past and present involves a consolidation of the community's story. The research gathers insights from the perspectives of domestic and international stakeholders, including government agencies, tourists, and local residents. The authors use a mixed-method approach of quantitative and qualitative research including literature reviews, surveys, interviews, and ethnographic observation. Findings indicate that Morocco experiences economic benefits from the investment in the restoration of sites that attract tourists and promulgate an identity of religious pluralism and openness. The authors foster a more comprehensive understanding of the present, exploring the various motivations behind different preservation measures and stakeholders.

Eva Meléndrez SEAS'27, Mechanical Engineering

Faculty Mentor(s) or Supervisor(s): Vijay Vedula
Title: Toward Modeling Cardiovascular Hemodynamics in Spaceflight: Benchmarking Approach Using the FDA Nozzle

Abstract: This study investigates how computational modeling can be applied to understand cardiovascular changes in microgravity. Spaceflight induces various changes such as fluid shift, vascular remodeling, cardiac adaptations, among others that presents risks to astronaut health. Current simulations often simplify or omit the dynamic role of the heart and large vessels due to the complexity of the model. To build a foundation for future cardiovascular flow simulations under microgravity, this project has two parts. First, a literature review that examines past experimental and computational work on cardiovascular adaptations in Low Earth Orbit (LEO) spaceflight. Secondly, computational skills are developed through the FDA nozzle benchmark, a model used to evaluate the trustworthiness of computational fluid dynamics (CFD) in the simulation of blood flow in medical devices. The nozzle benchmark serves as training in mesh generation, solver setup, as well as specifying boundary conditions. Additionally it serves as a source of validation against experimental and computational flow data. These skills are essential for accurately modeling complex blood flow and physiological conditions. By combining the current knowledge of space physiology with computational modeling, this lays groundwork for future simulations of blood flow in large vessels such as the aorta and cardiac chambers under conditions of microgravity.

Simone Miller CC'26, Biology, English

Faculty Mentor(s) or Supervisor(s): Emily Mace

Title: PLCG2-dependent natural killer cell dysfunction and disease variability

Abstract: Mutations in the PLCG2 gene disrupt immune cell signaling and are associated with diverse clinical outcomes, including natural killer (NK) cell dysfunction and autoinflammation. NK cells are white blood cells that help control infections and cancer by killing abnormal cells. However, inherited mutations in PLCG2 lead variable clinical manifestations. Some patients will experience autoimmune disorders, while family members with the same genotype can remain asymptomatic. This project investigated how loss of PLCG2 impacts NK cell function and explored monoallelic expression (MAE) as a possible explanation for variable clinical expression.
Using immunofluorescence imaging, PLCG2-knockout (-KO) NK cell lines were compared to the wild-type (WT) cells when conjugated with leukemia-derived (K562) and lymphoblastoid (721.221) target cells. PLCG2-KO cells displayed impaired polarization of perforin, a cytotoxic granule, towards the immune synapse, consistent with defective NK cell killing. Unexpectedly, these cells also exhibited increased phosphorylation of a downstream signaling protein, ERK, suggesting that compensatory signaling pathways may be activated in the absence of PLCG2. To evaluate whether MAE contributes to disease variability, we studied two siblings who carry the same gain-of-function PLCG2 mutation, but only one of whom developed autoimmune symptoms. We used digital droplet PCR (ddPCR) to measure the relative amounts of mutant versus normal PLCG2 transcripts in their immune cells. This approach provides a framework to test whether unequal expression of the two alleles helps explain differences in disease presentation.
Preliminary experiments in healthy donor cells highlighted the need for primer optimization before patient samples can be analyzed. Together, these findings confirm PLCG2's essential role in NK cell cytotoxicity and provide a framework to assess how unequal allele usage may underlie variable penetrance in PLCG2-associated disorders. This work advances our understanding of immune regulation and targeted therapeutic approaches.

Daniel Moon CC'26, Biochemistry, Mathematics

Faculty Mentor(s) or Supervisor(s): Sam Sternberg
Title: The Role of Arc in IS200/605 Regulation

Abstract: CRISPR-Cas systems have been the cornerstone of genetic engineering technology in the last decade. Rational engineering allowed scientists to improve these nucleases and create Cas9 and Cas12-based tools that were widely applied for research as well as therapeutic purposes. A recent study from our lab, as well as others, have found that an evolutionary

precursor to CRISPR-Cas12 protein, called TnpB, is natively encoded in IS200/IS605 transposons. TnpB is responsible of ensuring transposon re-installment after transposon excision, which is achieved through DNA cleavage followed by homologous recombination—the very same principle that has been used to introduce a changed DNA sequence during Cas9 and Cas12 nuclease-based gene editing in human cells. However, overexpression of nucleases in any cell might threaten its genome integrity. Incidentally, some TnpB proteins are natively associated with Arc, a small ribbon-helix-helix repressor, suggesting that TnpB nucleases might have a natural regulation mechanism in bacteria. In this study, we show that Arc has a repressive impact on TnpB expression within transposons by binding to the promoter region. In the ongoing work, we tackle the question of how this silencing affects transposon expansion and maintenance during the constant interplay between transposon and host fitness.

Hannah Moon SEAS'28, Chemical Engineering

Faculty Mentor(s) or Supervisor(s): Huimin Zhao (PI), Longyuan Shi (Graduate Mentor)
Title: Microbes as Sustainable Biofactories: Engineering Yeast Rhodotorula Toruloides for Triacetic Acid Lactone Production

Abstract: Triacetic acid lactone (TAL) is a valuable chemical precursor to many antibiotics, food additives, and fuels. However, traditional manufacturing methods for TAL rely on toxic catalysts and yield environmentally hazardous byproducts. A promising alternative is to genetically engineer microbial "factories," which can sustainably produce TAL using low-cost, eco-friendly biomass. Recent studies have integrated the 2-pyrone synthase gene (abbreviated as GhPS) into the genome of yeast Rhodotorula toruloides, which allows the organism to convert its intracellular Acetyl-CoA into TAL. While this makes Rhodotorula a prime candidate for TAL synthesis, the species lacks extensive research into its genetic engineering, inhibiting its potential yield. Previously, only five copies of GhPS have been successfully integrated into the Rhodotorula genome. A pressing question is if further overexpression of the GhPS gene continues to increase TAL production, or leads to diminishing marginal returns. This project engineered 114 variations of GhPS overexpression in Rhodotorula strains, then utilized precision fermentation to track each strain's TAL production relative to Rhodotorula with only five GhPS copies. The best-performing Rhodotorula overexpression strain increased TAL production by 17%, with a statistically significant p-value of 0.007. These findings validate continuous GhPS overexpression as an effective optimization strategy for Rhodotorula-based TAL production, increasing the yeast's capacity as a sustainable biofactory.

George Morgulis CC'26, Computer Science

Faculty Mentor(s) or Supervisor(s): Ethan Ritz
Title: Machine Learning for Negative Linear Compressibility

Abstract: Negative Linear Compressibility (NLC) is a highly unusual elastic phenomenon in which a material expands along a specific direction when subjected to uniform pressure. NLC is extremely rare, and elasticity data is limited: only about ten percent of entries in the Materials Project database have calculated elastic properties. Identifying NLC in a material is also computationally expensive, as it requires calculating its compliance tensor using Density Functional Theory (DFT). In this work, we propose a machine learning approach to identify candidate NLC materials for DFT validation. To quantify NLC, we consider the upper 3×3 subtensor of the compliance tensor and define the material's K-score as its smallest row sum. More negative K-scores indicate more pronounced NLC behavior, though our model is trained only as a binary classifier. We address class imbalance using a classification cascade across K-score thresholds, yielding progressively balanced training distributions. At its current stage, the model has successfully identified multiple new materials that exhibit NLC, including an entire family of materials with distinctive structural features; these predictions were subsequently verified using DFT. Our work underscores how data-driven methods can complement first-principles calculations in the search for materials with NLC.

Chloe Muller GS'28, Chemistry

Faculty Mentor(s) or Supervisor(s): Shruti Shrestha
Title: Fostering Inclusiveness in Physics for Undergraduate Women

Abstract: Women remain significantly underrepresented in the physics career path despite the notable increase in Bachelor's degrees awarded to women in STEM fields overall in the United States— from 17% in 1966 to 41% in 2021, as reported by the American Physical Society. This pronounced underrepresentation in physics is a pervasive global phenomenon evident across countries as economically and culturally divergent as the United States and Nepal. The gender gap across physics careers is a complex, systemic issue shaped by social and cultural biases, inequitable educational practices, and institutional barriers. Significant disparities emerge in early education and compound, discouraging persistence, limiting degree attainment, and

impeding career advancement for minority groups. This review identifies the drivers of disparities in undergraduate physics education, a pivotal stage in the academic-to-professional trajectory, where targeted reform can have a lasting impact on retention. Addressing these disparities requires the synthesis of established and emerging STEM equity models from international and institutional contexts, offering implementable reforms for physics departments in response to demonstrable institutional need. Strategies include mentorship programs, faculty bias training and search committees, targeted hiring, transparent retention and recruitment data, student leadership development, and outreach programs to engage diverse populations. Embedding such practices fosters environments that recognize systemic inequities while equipping students with the confidence and skills to navigate them. Culminating in a practical application of the insights gained in developing best practices, this review presents a detailed proposal for Penn State Brandywine's Physics Department, institutionally tailored to advance equity and cultural transformation for the department.

Kaylie Musard SEAS'27, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Sanat Kumar
Title: Particle Dispersion Controls the Gas-Separation Properties of Polymer-Grafted Nanoparticle Membranes

Abstract: Membranes that can efficiently separate gases are vital for reducing energy use and supporting cleaner technologies in areas such as energy production and chemical processing. A new class of membranes, made from polymer-grafted nanoparticles (PGNPs), has shown strong potential because of their ability to be tuned to balance permeability, selectivity, and mechanical properties. In this work, we highlight how the arrangement of nanoparticles plays a key role in membrane performance. Although nanoparticles may initially be evenly dispersed in solution, the process of attaching polymer chains to their surfaces can cause them to clump together. This clumping reduces the effectiveness of the membrane by limiting gas flow compared to membranes formed from evenly dispersed nanoparticles. To address this challenge, we introduced a protective layer around the nanoparticles before attaching the polymer chains. This strategy prevented clumping, maintained an even distribution of particles, and led to membranes with significantly higher gas permeability. These findings show that the performance of polymer grafted nanoparticle membranes depends not only on the materials used, but also on controlling particle dispersion throughout the entire preparation process. By emphasizing the importance of nanoparticle arrangement, this work provides new insights for designing next generation membranes that can make gas separation more energy efficient and sustainable.

Luca Nashabeh CC'26, Mathematics, Physics

Faculty Mentor(s) or Supervisor(s): Liang Fu
Title: Plasmon Mediated Superconductivity in Asymmetric Electron-Hole Bilayers

Abstract: We consider equal density, mass asymmetric electron-hole bilayers as a platform to study various quantum phases and their transitions. Owing to the independently tunable density parameter in both layers and the interlayer distance, the system has a three dimensional phase space, with the interplay between kinetic energy and the Coulomb interaction giving rise to standard liquid, crystal, and condensate phases, as well as a mixed liquid-crystal phase analogous to an alkali metal. Motivated by metallic hydrogen, we predict this mixed phase to display robust superconductivity over a range of densities and interlayer spacing, potentially even at high temperatures. Possible experimental realization of these effects in TMD or mixed TMD-graphene heterostructures is discussed.

Mark Nashi CC'28, Chemistry, Human Rights

Faculty Mentor(s) or Supervisor(s): Luis Campos
Title: Synthesis of Catenanes to Produce Deformation-Resistant Tanglemers

Abstract: Polymers with high crosslinking density struggle to deconcentrate stress and withstand deformation. Polymers such as plastics, rubbers, and hydrogels break down over time and are hard to recycle. Tanglemers, a subset of polymers in which entanglements compose a higher density than crosslinks, have been shown to display increased toughness and stiffness, while withstanding deformation better over time. However, a struggle within this field is synthesizing these elastomer polymers. This study attempted to synthesize catenanes–molecules with intertwined ring structures–with attached mechanophores to produce entangled products. The mechanophore, maleic anhydride, would undergo epoxide ring-opening to break the sacrificial cyclobutane bond, which would leave behind an entangled network. Preliminary NMR results show that the third product of the synthesis was successful: the alkoxy group was attached to the phenanthroline via an SN2 reaction with 2-(2-chloroethoxy)ethan-1-ol, and this implies the success of the final product. One drawback to the methodology performed in this study was the amount of waste generated from the seven synthesis steps;

thus, further research should attempt to find more efficient synthetic routes that minimize waste and preserve yield.

Joyti Nath CC'28, Biology

Faculty Mentor(s) or Supervisor(s): Peter Andolfatto
Title: Understanding the Genetic Basis of Traits Underlying Phenotypic Differences in Domestic and Wild Silkmoths

Abstract: Domestication of the silk moth (Bombyx mori) has produced profound genetic and phenotypic differences from its wild ancestor, B. mandarina, particularly in traits related to silk yield. Understanding the genetic basis of these traits is essential for studying both domestication and hybrid incompatibilities. To build toward this goal, the population of 323 B. mori × B. mandarina F2 individuals were mapped in Summer 2025. Starting with ~700 eggs, larvae were reared through to adulthood under controlled conditions, preserving multiple tissue types for downstream analysis. For each individual, phenotypic data was collected, including cocoon weights and cocoon images, which can later be analyzed for color variation. Exploratory analyses of these new data, together with archived F2 and backcross phenotypes from 2024, revealed variation in cocoon weights and colors across crosses. In particular, backcross individuals (carrying a higher proportion of the B. mori genome) tended to produce heavier cocoons than F2 individuals, consistent with expectations under domestication. Although these differences were not always statistically significant, the observed patterns suggest a genetic basis that can be investigated further. Moving forward, there's a plan in motion to generate low-coverage whole-genome sequencing data for both the 2024 and 2025 datasets. By combining phenotypic measurements with genetic data, it will be possible to map cocoon weight and color variation to specific genomic regions, clarifying whether traits are associated with B. mori– or B. mandarina–derived alleles. This approach will provide new insights into domestication as a selective force and into speciation processes in silk moths.

Alex Nath SEAS'26, Chemical Engineering

Faculty Mentor(s) or Supervisor(s): Juliana Silva Alves Carneiro
Title: Nickel Nanoparticle Exsolution from Perovskites for Durable Catalysts

Abstract: Catalysis is an emerging field focused on designing materials that accelerate chemical reactions and improve efficiency, ultimately enhancing chemical production across many industries. By developing catalysts that are both highly active and stable, researchers aim to make chemical processes faster, more selective, and more sustainable. Perovskite oxides (ABO_3) are dynamic and adaptable catalyst materials that can host transition metals within their lattice while remaining stable under demanding conditions. This study investigates nickel (Ni) in two forms: conventional nanoparticles deposited on the surface of perovskites, and "socketed" nanoparticles that emerge from the lattice through a process called exsolution. Nickel particles deposited on the surface often lose effectiveness because carbon can build up and block active sites (coking), or particles can clump together at high temperatures (sintering). In contrast, exsolved particles are anchored into the oxide lattice, which improves stability, reduces carbon buildup, and prevents deactivation. The materials examined in this work demonstrate this behavior clearly. Under reducing conditions, nickel is exsolved from the perovskite lattice, producing highly dispersed socketed nanoparticles directly within the structure without the need for external deposition. This behavior highlights the versatility of perovskite oxides and their ability to generate durable catalysts through built-in nanoparticle formation. The systems were characterized to confirm the morphology, composition, and lattice origin of the nickel nanoparticles. CO_2 gas was used as a model reaction because it is chemically inert and highly relevant to climate change mitigation, providing a meaningful way to evaluate the activity and stability of these catalysts.

Aneesha Needamangala CC'28, Data Science

Faculty Mentor(s) or Supervisor(s): Meredith Landman
Title: Modeling Endangered Language Shifts and Revitalization: Applying the Abrams-Strogatz Model to 'Ōlelo Hawai'i

Abstract: This project investigates the dynamics of language endangerment and revitalization in Hawai'i from a quantitative perspective by applying the Abrams-Strogatz model to the indigenous Hawaiian language, 'Ōlelo Hawai'i, and English. The Abrams-Strogatz framework is a mathematical model that examines the competition between two languages in a given society, taking into account how factors such as the perceived social and economic value of a language can influence language adoption or decline. By varying parameters, such as the prestige of a language, this model explores how educational policies, media presence, and community use of a language can enable its survival. In employing this mathematical model, this project took on a mixed-methods approach. A qualitative analysis on historical milestones in the decline and resurgence of 'Ōlelo Hawai'i supplemented the construction of a time-series plot of the decline and resurgence of 'Ōlelo Hawai'i using the Abrams-Strogatz model. The initial ban of 'Ōlelo Hawai'i in 1896, the halting of newspaper publications in 'Ōlelo Hawai'i of 1947, and

the launching of Hawaiian immersion preschools in 2002, are all notable milestones that marked a shift in the number of fluent speakers and the prestige of ʻŌlelo Hawaiʻi, as represented through the Abrams-Strogatz model. Ultimately, this project seeks to contribute a quantitative perspective to the study of language endangerment, yielding insights into how math modeling can be implemented to better understand language dynamics.

Victoria Ngai CC'26, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Alexis Coslick
Title: The Impact of Coach-Athlete Gender Concordance on Eating Disorders in Female Wrestlers

Abstract: Objective: To evaluate the impact of coach-athlete gender concordance on disordered eating behaviors in high school and collegiate female wrestlers in the United States. Methods: A cross-sectional survey was administered to female wrestlers and their coaches during the 2025 winter sports season. Survey domains included athlete eating behaviors (EDE-Q items), comfort discussing body weight and nutrition with coaches, and coach knowledge and practices regarding nutrition, weight management, and disordered eating. Comparisons were made between female wrestlers with male versus female coaches and between male versus female coaches. Results: Surveys responses were collected from 170 female wrestlers and 111 coaches. Wrestlers with female coaches reported lower frequencies of disordered eating behaviors and greater comfort discussing weight, body composition, and eating habits than those with male coaches. Although body mass indices (BMIs) were similar across groups, female wrestlers with male coaches were more likely to report missed menstrual periods. Female coaches more often emphasized athlete well-being, mental health, and referral to qualified professionals, while male coaches more frequently provided direct nutrition and weight recommendations. Athlete perceptions paralleled these patterns, with female coaches perceived as fostering more supportive, body-positive team environments. Conclusion: Coach gender was associated with differences in female wrestlers' reported eating behaviors, comfort with sensitive discussions, and perceptions of support. Findings suggest a potential protective role of female coaches in mitigating disordered eating risk and underscore the need for targeted education and training for male coaches to ensure the safety and comfort of female wrestlers.

Andrew Nguyen CC'27, Biology, Psychology

Faculty Mentor(s) or Supervisor(s): Claudia Doege

Title: Refining an In Vitro Differentiation of Human Arcuate-Like Neurons Method

Abstract: The human hypothalamus plays a critical role in regulating metabolism, energy, and reproduction, yet how these neurons develop in humans is not well understood. This project aims to map the developmental fate of pro-opiomelanocortin (POMC) progenitors and tests whether these cells can mature into arcuate-like neurons that express agouti-related peptide (AGRP), neuropeptide Y (NPY), and kisspeptin-1 (KISS1). Post-mortem human hypothalamus sections were characterized by BaseScope in situ hybridization to identify the arcuate nucleus for further multiomic study. In parallel, a tamoxifen-inducible POMC lineage tracer was engineered into H9 human embryonic stem cells, which were differentiated toward a hypothalamic fate using patterning signals and morphogens present in the human arcuate nucleus. These neurons were transplanted into immunodeficient mouse hypothalami to evaluate maturation of in vitro grown neurons in an in vivo environment. These neurons survived, migrated to the arcuate region, and activated the lineage reporter, indicating the presence of endogenous POMC expression. However, apoptosis was observed after transplantation, and co-injection of the TNF-alpha inhibitor adalimumab is being evaluated to improve neuronal survival. The same in vitro-grown neurons were exposed to bone morphogenic protein 4 (BMP4) for varying durations during differentiation. They were analyzed using quantitative polymerase chain reactions to determine which genes were expressed and whether the expression was similar to those of a real human hypothalamus. AGRP was not detected, meaning that the additions of BMP4 were not successful in producing more mature arcuate-like neurons. The results establish the groundwork for studying hypothalamic neurogenesis and advancements in obesity-related cell therapies.

Han Nguyen-Luu GS'27, Sustainable Development

Faculty Mentor(s) or Supervisor(s): Beizhan Yan
Title: Identification and Quantification of Micro- and Nano-plastics in Common Soft Drinks in the US

Abstract: Microplastics (≤5 mm) have been detected in various environments and are impacting over 1,300 aquatic and terrestrial species. Alarmingly, they have also been found in human tissues, organs, and bodily fluids, including blood cells, sputum, lungs, liver, and breastmilk. These particles are common in everyday products such as food, beverages, and cosmetics, and they can easily enter the human body through ingestion, inhalation, and skin

absorption. Nanoplastics (<1 μm) can fragment from microplastics and have the potential to cross biological barriers. However, research on nanoplastics is still limited due to a lack of reliable analytical techniques for their detection and quantification. Thus, this study aims to fill that research gap by examining the presence and concentration of micro- and nanoplastics (MNPs) in popular soft drinks in the U.S., as this represents a significant pathway for human exposure. To conduct this research, soft drinks were processed using oxidation techniques to eliminate sugars and colorants, making them suitable for analysis through scanning electron microscopy (SEM) and stimulated Raman spectroscopy (SRS). Preliminary SEM results show that the detected materials vary in size and shape and exhibit moderate carbon concentrations, which align with the carbon-based structure of plastic polymers. SRS analysis indicates that a 12-ounce can of Coca-Cola contains approximately 3.74×10^6 MNPs, of which 78% are nanoplastics. Notably, nearly 50% of the identified MNPs were found to be polyethylene. Ongoing research will further investigate the concentration of MNPs in different soft drinks and container types, including glass and plastic bottles, as well as cans.

Olivia O'Driscoll SEAS'26, Computer Science

Faculty Mentor(s) or Supervisor(s): Kristy Brock
Title: Early Treatment Changes in Radiomics and Blood Biomarkers Predict Radiation-Induced Liver Disease

Abstract: Radiation-induced liver disease (RILD) is a potentially life-threatening complication of liver cancer radiotherapy that remains difficult to predict. We retrospectively analyzed 102 patients to test whether combining clinical variables, laboratory biomarkers, dose-volume metrics, and CT-based radiomics measured during therapy improves prediction. RILD was defined within four months post treatment as any of: Child–Pugh increase ≥2 points (N=16); alkaline phosphatase >2× upper limit of normal or >2× baseline (N=34); or transaminases >5× upper limit of normal or >5× baseline (N=6). All patients had contrast-enhanced planning CT and daily non-contrast CT-on-rails before each fraction (mean 17±7 fractions over 21±9 days). Scans were co-registered with biomechanical deformable registration to enable voxel-wise comparison, and radiomics features were extracted from CT-on-rails. Non-imaging features included blood tests obtained 14±7 days before treatment, 3±3 days before mid treatment, and 3±3 days before the final fraction; dose-volume metrics; liver and target volumes; and demographics and pathology. We assessed eight feature-selection strategies and eight machine-learning algorithms with 10-fold cross-validation at pre-, mid-, and end-treatment time points, with/without imaging. Performance was measured by AUC. The delta AUC with 95% confidence interval between models was assessed via bootstrapping on the pooled out-of-fold predictions.
The mid-treatment model with imaging features had an AUC of 0.87 ± 0.07, which was significantly better than all other models available at the same timepoint. The end-of-treatment model had an AUC of 0.91 ± 0.14, which was not significantly better than the mid-treatment model with imaging.

Yuki Ogawa CC'27, Computational Biology

Faculty Mentor(s) or Supervisor(s): Anthony Fitzpatrick
Title: Untangling the Cryptic Amyloid Fibril in Preeclampsia

Abstract: Preeclampsia, a hypertensive pregnancy-specific disorder, is a leading cause of neonatal and maternal mortality affecting 5-8% of pregnant people globally. Although proteinuria is a hallmark symptom, there is no reliable prognostic factor, and the lack of diagnosis remains the primary cause of preeclampsia-related deaths. Survivors also appear to face higher risks of neurodegenerative diseases later in life. Prior studies have shown that amyloid fibrils, commonly associated with neurodegenerative disease, are present in the preeclamptic urine, but the identity of the fibril-forming protein has not been determined. This project aims to identify the protein that forms the amyloid fibril in the urine of preeclamptic patients and to elucidate the mechanisms by which affected individuals may later develop neurodegenerative diseases. Pull-down mass spectrometry was performed to profile proteins in preeclamptic urine using the bacterial binding domain-specific antibody of uromodulin, the most abundant urinary protein. This approach successfully uncovered the urinary proteome of uromodulin and how it changes in preeclampsia. Cryo-electron microscopy was also utilized to visualize the structure of the urinary amyloid fibrils, generating a three-dimensional map of the amyloid fibrils that is ready for atomic model building. These advances will enable definitive identification of the fibril-forming protein, lead to a better understanding of pathological mechanisms linking preeclampsia with neurodegenerative disease, and lay the groundwork for improved urine-based diagnostic methods and risk stratification.

Kamtoya Okeke CC'28, Cognitive Science

Faculty Mentor(s) or Supervisor(s): Alec L Joyner
Title: When The World Ends: A Comparative Analysis of Destruction Myths

Abstract: Some of the earliest human writing grapples with essential questions of time and death: What does it mean? How does it happen? Why? These eschatological questions are addressed in destruction myths, narratives driven by large-scale destruction of the physical world. This comparative study examines destruction myths in order to define the literary function of destruction as a genre of mythology, and consider the relevance these ancient myths have in the modern day. This project investigates this question through a dual approach of close reading and comparative interpretation of four destruction myths: the Bible's Revelation, Norse Ragnarok, Hindu Naimittika Pralaya, and the Aztec Five Suns. Using the literary frameworks given by modern genre theory, which posits that narratives are changeable, interpretable, and reflective of cultural anxieties, needs, and values, this study identifies three main conclusions: (1) The literary role of destruction is primarily soteriological. Rather than fatalistic apocalypticism, destruction acts as a form of renewal and signaling of future hope. (2) As a genre of mythology, destruction is defined additionally by its tensions between reality and fantasy, salvation and immortality, and human and otherworldly forces. (3) These texts point to universal aspirations towards faith, perseverance, mercy, and justice, and societal fears of moral and political corruption, divine judgement, and nonbeing. Collectively, these findings illustrate the role of destruction in mythology, not as a form of literature removed from reality, but as a reflection of the societal framing which underpins historical and modern day politics, social structures, and ideological narratives.

Chase O'Malley SEAS'26, Chemical Engineering

Faculty Mentor(s) or Supervisor(s): Allie Obermeyer
Title: Engineered Protein Nanoparticles with AI-Generated Minibinders as Precision Cancer Therapeutics

Abstract: Cancer remains a leading cause of mortality worldwide, with current therapies often limited by systemic toxicity and poor specificity. Protein-based nanoparticles offer a promising alternative for the safe and effective delivery of protein therapeutics, including gene-editing therapeutics such as CRISPR/Cas9. Here, elastin-like polypeptide (ELP)/Histone-5 (H5) fusion proteins were engineered to self-assemble into complex coacervate core micelle (C3Ms) nanoparticles for the encapsulation and targeted delivery of therapeutic protein cargos. Using a machine learning platform deployed on Columbia University's high-performance computing cluster, cancer-specific protein minibinders were designed and incorporated into these fusion proteins, enabling the active chemical targeting of specific tumor cells. Utilizing genetically supercharged variants of green fluorescent protein (GFP) as a model cargo, C3Ms were formed and characterized via dynamic light scattering (DLS) and transmission electron microscopy (TEM). Stable micelle formation was observed at a positive charge fraction of 0.8, yielding nanoparticles with a mean diameter of 26.6 nm (number-weighted), a z-average hydrodynamic radius of 41.7 nm, and a low polydispersity index (0.143). Rational engineering of the H5 region enhanced micelle stability under physiological salt conditions through increased charge density and the introduction of disulfide crosslinks. The micelles also displayed pH-responsive disassembly, suggesting potential for endosomal escape and programmed disassembly. Cellular uptake experiments in MDA-MB-231 breast cancer cells revealed enhanced internalization of minibinder-functionalized micelles compared to untargeted controls, as well as evidence of endosomal escape. Collectively, these results demonstrate the feasibility of rationally engineered, fully protein-based nanoparticles as modular, tunable, and biocompatible platforms for targeted intracellular protein therapeutic delivery. Ongoing efforts aim to fully characterize the delivery efficiencies of these particles, and extend this system to Cas9 and other therapeutically relevant proteins, establishing a foundation for protein-based engineered nanocarriers in future cancer therapies.

Felix Ortiz de Montellano CC'26, Biology

Faculty Mentor(s) or Supervisor(s): Laura Landweber
Title: Investigating a novel role for DNA-cleaving enzymes in the complex genome of the ciliate Oxytricha trifallax

Abstract: The single-celled eukaryote Oxytricha trifallax is notable for its remarkably dynamic genome, which undergoes extreme remodeling during sexual development. Almost 15% of its germline genome is composed of transposons, also known as "jumping genes," DNA sequences that can move throughout the genome via the DNA-cleaving transposase proteins they encode. Unusually, most of Oxytricha's transposons are capable of producing functional, DNA-cutting, enzymes. Its extensive genome remodeling and high amount of active transposases makes Oxytricha an ideal model organism to study novel biological roles for these enzymes. This lab's past research has suggested that transposases might play a role in the extensive genome rearrangement the cell undergoes by helping cut the DNA. A potential technique to investigate this hypothesis is Chromatin Immunoprecipitation Sequencing (ChIP-seq). ChIP enriches DNA fragments based on their binding to a specific protein. Pairing it with sequencing enables the locations of the chosen protein (transposases for this project) to be identified across the genome. If this anti-transposase ChIP-seq experiment reveals enrichment of transposases near sites of DNA cleavage, it would indicate their participation in Oxytricha's genome remodeling. A key aspect of this summer project was optimizing this protocol. First, the antibody and immunoprecipitation

protocols for enriching the TBE transposase proteins were verified in genetically modified E. coli. The immunoprecipitation will be verified in Oxytricha, after which the ChIP-seq experiment can be performed. Another aspect of this project was use of a technique similar to ChIP-seq, MeDIP-seq, which instead enriches methylated DNA and was performed in Oxytricha.

Isabella Palit SEAS'28, Electrical Engineering

Faculty Mentor(s) or Supervisor(s): Ioannis (John) Kymissis
Title: Developing Software to Enable the Pneumatic Nozzle Printing of Organic Electronics

Abstract: Organic semiconductors have great potential to miniaturize fast neutron detection, as their low atomic numbers allow for more prevalent interactions with the particles. This system would allow one to control the crystallization and patterning of various organic inks, which are difficult to work with using standard fabrication techniques. A custom-made pneumatic printer had been built to enable printing with such organic inks. However, the printer was limited to printing straight lines and lacked any automation capabilities, thus making it insufficient for fully printed electronics. For this work, the existing MATLAB-based application was expanded to add functionality for rectangles and curved shapes like circles of custom sizes. Additionally, a file parsing feature was added to allow reading in files from standard design apps like AutoCAD, Inkscape, and LayoutEditor. The LayoutEditor file parsing feature was further extended to allow for printing of more complex shapes, like bezier curves and text. Also, by utilizing the layer feature in LayoutEditor, the printer can now print multi-ink designs, thus enabling the fabrication of fully-printed multi-layer organic electronics, e.g., PVDF with Readi-Cat and neutron-detector devices. Additionally, multiple new organic inks at various concentrations were formulated, printed, and characterized to optimize properties like mobility and line thickness. This printer-app system enables fabrication of soluble materials with tunable crystallinity properties to fabricate devices for a wide variety of applications.

Ben Parkhurst CC'26, Linguistics

Faculty Mentor(s) or Supervisor(s): Susannah Levi
Title: Rates of Uptalk in Computer-Directed Speech

Abstract: Linguists and speakers of American English are acutely aware of uptalk, a phenomenon in which speakers end declarative statements with a question-like rising intonation pattern. Uptalk is an established feature of many American English dialects, despite negative attitudes towards users of uptalk in previous literature (Warren 2016; Lakoff 2004; Tomlinson & Fox Tree 2011) and public discourse (Davis 2010; Rhodan 2014; Dallet 2014). This study seeks to build on existing works describing Uptalk's function of signaling the speaker's turn in by examining whether it is still present in the absence of an interlocutor. In this study, 252 participants were recruited via Prolific and surveyed as part of a larger study of speaker pitch using Gorilla. Data were gathered from two tasks: In the first, participants detailed how they would make a PB&J, and in the second, they described their microphone setup. Audio was transcribed using OpenAI's Whisper, aligned with the Montreal Forced Aligner, and divided into sentences using PyToBI and Praat. After elimination due to audio quality and incomplete instructions, 168 participants remained for the PB&J task, and 169 remained for the microphone description task. In the PB&J task, 258 of 636 sentences (40.57%) displayed uptalk, while 72 of 281 sentences (25.26%) in the microphone description task demonstrated uptalk. These preliminary results suggest uptalk's social function may apply to asynchronous conversations, as participants knew their files would be listened to, but further analysis and comparison to corpora of conversations is needed to draw stronger conclusions.

Glenn Paul GS'27, Sociology

Faculty Mentor(s) or Supervisor(s): David Stark
Title: The Art of Chaos: How Does NYC Nightclub Reinvent Nightlife through Organised Innovation

Abstract: This study examines how the New York City nightclub — The Stranger uses space, creativity, and interaction to shape new forms of community and innovation within the experience economy. The central question asks how The Stranger's spatial design, creative friction, and recombination of ideas transform the dynamics of interaction, secrecy, and belonging among its attendees. The research is based on a mixed-methods approach that combines direct observation in the nightclub, interviews with its producers and founders, and informal conversations with guests. A narrative ethnography style is used, blending personal accounts with theoretical analysis to capture the layered dynamics of the space. Supporting materials include interview transcripts and photographic documentation, which provide a grounded basis for interpretation. This project also draws from broader literature on the relationship between physical space and social life, the role of design in fostering collective creativity, and organizational practices that enable innovation. Influences include Andersson's work on social dynamics, Kries's studies of nightclub culture, and theories of

innovation and collaboration advanced by Hargadon, Stark, and Powell. The analysis also engages with Joseph Pine and James Gilmore's writing on the experience economy and Arjo Klamer and Michael Hutter's research on value creation in creative industries. By situating The Stranger within this body of scholarship, the study shows how the nightclub functions not only as entertainment but as a site of experimentation, social connection, and cultural production.

Kevin Phelan CC'28, Neuroscience

Faculty Mentor(s) or Supervisor(s): Alfredo Spagna
Title: Limitations in the link of frontal positivity and metacognitive confidence in lecture-based learning

Abstract: Perceptual confidence has been linked to a frontal-positivity (FP) event-related potential, but whether this marker generalizes to metacognitive confidence during learning remains unclear. This study attempts to conduct a preliminary evaluation of the transferability of FP correlates to the more learning pertinent, metacognitive confidence that accompanies appraisal. To do so 10 participants were selected from a broader study about attention to undergo analyses, and three had to later be excluded due to faulty EEG readings resulting in N=7. From these participants EEG measurements were collected using a as they answered questions about an approximately one hour lecture and Confidence level was appraised using retrospective confidence ratings (either very confident or not confident) following the questions about lecture content. The peak level of activation in the both frontal channels (AF7, AF8) was found for the -1000 to 0ms window preceding response. The FP of the higher confidence participants and lower confidence participants exhibited no statistical difference prior to response with a $p = 0.799$ and Hedge's $g = 0.208$. Limitations include small sample size, limited number channels, and only two bins of confidence. Such a result highlights the need for further research into feasible ways of measuring real-time confidence to incorporate broader scalp analyses and trial-level modeling, and test additional neural markers and task designs. Clarifying whether these potential shared substrates can be easily measured within context will inform the design of eeg based indicators of students' self knowledge.

Lyla Prasad CC'28, Biophysics

Faculty Mentor(s) or Supervisor(s): John F Hunt
Title: Investigating CFTR Domain Asymmetry: NBD1 vs. NBD2 in Cystic Fibrosis

Abstract: Cystic fibrosis (CF) is a life-threatening genetic disorder, mostly prevalent in the western world, caused by mutations in the Cystic Fibrosis Transmembrane Conductance Regulator (CFTR) protein. CFTR functions as an ion channel for salt and water transport across epithelial cells in the lungs and other organs. Proper CFTR activity depends on the precise folding and assembly of four major domains: two nucleotide-binding domains (NBD1 and NBD2) and two transmembrane domains (TMD1 and TMD2). Biochemical studies show asymmetric functioning between the NBDs in controlling protein folding and stability, with NBD1 playing a particularly critical role. However, the structural basis of this difference has not yet been explored. Using cryo-electron microscopy, 3D structures of detached NBD1 versus detached NBD2 from their partner transmembrane domains of CFTR were compared. Loss of NBD1 destabilises the intracellular loops that anchor TMD1, while loss of NBD2 leaves TMD2 largely intact. These findings highlight that NBD1 functions as a folding scaffold for CFTR, whereas NBD2 is comparatively dispensable for structural stability. These domain-specific effects explain why mutations in NBD1, such as the F508del mutation present in ~90% of CF patients are particularly harmful. It also illustrates how small-molecule corrector drugs restore CFTR function by stabilising NBD1-TMD1 interactions.

Christina Quinones CC'27, Cognitive Science

Faculty Mentor(s) or Supervisor(s): Claudia Lugo-Candelas
Title: Acculturation and Resilience Against Adversity in Latino/Hispanic Adolescents

Abstract: The literature concerning acculturation and the Latino and Hispanic population in the United States presents largely inconsistent findings. Many studies suggest that the U.S. and brain function confer resilience to adversity. Berry et al. (1997) provide four culturation strategies: assimilation, integration (biculturalism), separation, and marginalization (detachment). Assimilation involves adopting mainstream culture and doing little to maintain ethnic culture. Separation entails a rejection of the mainstream culture, maintaining ethnic culture, and integration involves integrating both cultures. Marginalization reflects a rejection of both cultures. Our research addresses existing gaps, measuring acculturation rather than acculturative stress or ethnic identity longitudinally. Additionally, our study investigates the impacts of intergenerational acculturative gaps, focusing on Latino and Hispanic adolescents using The Adolescent Brain Cognitive Development (ABCD) Study, from baseline to the two-year follow-up. Acculturation strategies will be measured as a moderator using the Vancouver Index of

Acculturation and the Phenx Acculturation Survey. Resilience will be operationalized as the extent to which adversity correlates with negative mental health, cognitive, and brain function outcomes. Based on previous studies, we hypothesize that biculturalism will be associated with greater resilience against adversity as indicated by less externalizing and internalizing symptoms, better cognitive and executive function, and emotional regulation. We additionally hypothesize that acculturative gaps correlate with worse cognitive function, emotional regulation, and externalizing issues.

Amaya Quintana CC'27, Ethnicity and Race Studies, Sociology

Faculty Mentor(s) or Supervisor(s): Cristina Mora
Title: Latino Political Attitudes Across California; Assessing Gender and Place Differences

Abstract: This study explores how Latino voters in Sonoma County, California make sense of class, gender, and political identity in a region where 29% of eligible Latino voters supported the Republican Party. Latinos make up 40% of California's population, a state with the 4th largest economy in the world. How do the socio-economic environments in which Sonoma County Latinos are located help them understand our economy? Conducting ten in-depth interviews with Latino residents across gender and age groups, this study examines how lived experiences shape political beliefs. The findings show that Latino residents' understanding of class is often shaped more by their upbringing than by their current economic status, with many blurring the lines between working and middle class. Those experiences influence their political preferences and how they identify with party platforms. Many interviewees from single-parent households expressed diminished attachment to traditional gender roles, often viewing gender as less relevant in shaping their political views. In contrast, those who grew up in two-parent households felt that gender has a big impact on the ways in which they view politics today. Overall, the findings suggest that geography, class history, and family structure all play a significant role in shaping the political outlook of Latino voters in Sonoma County.

Shean Rahman SEAS'27, Applied Physics

Faculty Mentor(s) or Supervisor(s): Carlos Paz-Soldan
Title: ELM State Classification Using Machine Learning and Hybrid Deep Neural Networks

Abstract: This project focuses on improving the ability to detect and classify certain plasma behaviors that can disrupt experiments in magnetic fusion devices called tokamaks. In these devices, instabilities known as edge-localized modes (ELMs) can damage equipment and reduce performance. Scientists can sometimes suppress these instabilities using small, controlled magnetic perturbations, but the effectiveness of this method can vary. To better predict and control these events, this project develops machine learning models that classify plasma states using data from the DIII-D tokamak in San Diego, CA. Two main approaches were tested: a Random Forest classifier, which identifies patterns in data by combining many decision trees, and a hybrid deep learning model combining convolutional neural networks (CNNs) and bidirectional long short-term memory (BiLSTM) networks with an attention mechanism, which can track how plasma conditions change over time. The models were trained and tested on hundreds of plasma shots that had been labeled according to whether ELMs were suppressed, mitigated, dithering, or fully active. The deep learning model achieved up to 95 percent accuracy in identifying binary suppression states, while the Random Forest model provided more modest accuracy but greater physical interpretability. Dimensionality reduction techniques such as PCA and t-SNE revealed that plasma states could not be easily separated through simple visual inspection, highlighting the importance of models that can learn subtle, multi-dimensional relationships in the data. Future work will focus on refining the architectures, enabling real-time classification for control systems, and expanding the dataset to improve robustness.

Iniya Raja CC'27, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Jack Grinband
Title: Improving Congruency Effect Reliability Through Speed-Accuracy Tradeoff Correction

Abstract: In the study of attention and self control, understanding how people manage conflicting information is a key aspect. One common measure of this is the Congruency Effect, which compares how quickly or accurately people respond in situations where there is distracting versus non-distracting information. Canonical response conflict tasks have often shown only moderate reliability, raising recent concerns. One frequent solution has been to increase the number of collected trials, with some researchers proposing 1,000 trials per participant. Such high thresholds complicate the interpretation of past studies, significantly raise the cost of future work and are generally difficult to implement in many clinical populations. Instead, this study suggests a different approach, finding that much variability comes not from

random noise but from differences in strategy, specifically speed-accuracy tradeoffs, across sessions. In some sessions, participants may be quicker and thus more likely to make mistakes, while in others they may be slower and less error prone. Such shifts are not representative of real changes in the Congruency Effect, but effectively inflate error in many standard analyses. Using drift diffusion modeling, controlling for speed-accuracy tradeoffs greatly reduces session to session variability, ultimately revealing that reliable estimates of the Congruency Effect can be achieved with fewer than 200 trials. This modeling approach provides a more practical and reliable way forward for studies on attention and control.

Nidhi Ram CC'28, Mathematics, Middle Eastern, South Asian, and African Studies

Faculty Mentor(s) or Supervisor(s): Sen Pei
Title: Spatial Machine-Learning Based Prediction of Concentrated Animal Feeding Operation Locations in the Midwestern United States

Abstract: Concentrated Animal Feeding Operations (CAFOs) play a significant role in shaping environmental risk and zoonotic disease emergence, including outbreaks of highly pathogenic avian influenza H5N1. As the need to understand and model the emergence of HPAI H5N1 intensifies, it is necessary to consider the spatial distribution of CAFOs, given the increased cross-species viral transmission. However, no comprehensive dataset of CAFO locations currently exists for the United States. This project develops a semi-supervised machine learning framework to estimate CAFO counts at a 10 km x 10km grid resolution, with the goal of improving coverage in underreported states. We assembled a dataset of known CAFO locations across 30 states from state-level records, linked with predictors including population, farm and livestock counts, distance to meat processing facilities, agricultural employment, methane levels, canopy cover, soil and manure nutrients, and environmental justice indices. County-level predictors were downscaled to the grid-level resolution using a Bayesian implementation of intelligent dasymetric mapping that incorporated ancillary land cover data. Initially focusing on the Midwest, we developed a spatial model to predict CAFO counts per grid with the known locations and predictors. Due to the high frequency of zero counts, we trained XGBoost regression models on a labeled dataset constructed using negative downsampling. The latest models achieved out-of-sample R2 scores up to 0.63 in spatial cross-validation. With further refinement, these predictions will be used to generate a dataset of estimated CAFO density, enabling future efforts to model HPAI H5N1 dynamics and assess the environmental and public health risks associated with CAFOs.

Mia Raneri SEAS'26, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Tal Danino
Title: Engineering therapeutic probiotics to target and treat brain tumors

Abstract: Glioblastoma is an aggressive and treatment-resistant brain cancer with limited therapeutic options. Localized, sustained drug delivery directly into tumors could overcome many limitations of current treatments and conventional therapies, including poor drug penetration and systemic toxicity, and engineered bacteria offer a promising strategy for such an approach. This project applied synthetic biology to engineer E. coli strains capable of delivering therapeutic payloads directly into glioblastoma tumors, thus reducing off-target toxicity. First, the E. coli was engineered to eliminate inflammation and reduce risk, and this strain alone led to prolonged survival in tumor-bearing mice. Several candidate toxins and bioactive molecules were selected for their potential to target diverse tumor cell populations, addressing the highly heterogeneous nature of glioblastoma. Therapeutics were chosen based on either their ability to directly induce tumor cell death or to elicit a robust immune response against tumor cells. Engineered bacterial strains were constructed using molecular cloning techniques, and first tested in glioblastoma cell cultures, where cell viability assays quantified therapeutic efficacy. Strains were subsequently evaluated in vivo through intracranial injection in mouse models bearing grafted glioblastoma tumors. Following administration of bacteria, survival curves, body weight measurements, and bacterial presence within tumors and other vital organs were monitored to assess both efficacy and off-target effects. Together, this work demonstrates the feasibility of using engineered bacteria for precise, localized therapeutic delivery and provides a foundation for the development of clinically translatable bacterial therapies for the treatment of glioblastoma.

Arjun Ratan CC'28, Art History, Classics

Faculty Mentor(s) or Supervisor(s): Gareth Williams
Title: Latin and Its Impact on Youth Literacy in NYC Public Schools

Abstract: Arjun Ratan spent his first summer as a Laidlaw Research Scholar conducting research on the impact of Latin instruction on youth literacy rates in public schools throughout New York City. His project, supervised by Professor Gareth Williams of Columbia's Classics Department, followed a mixed-methods approach that included both quantitative and qualitative data

collection and analysis seeking to answer two main questions: the impact of Latin on literacy and how accessibility varies with socioeconomic status and school resources. As a part of the qualitative component, Ratan began by compiling relevant scholarship into an annotated bibliography of six key sources.. Ratan also conducted 20-30 minute oral history interviews with five educators and specialists who spoke to Ratan about their first-hand experience of the effect of Latin on youth literacy as defined by proficiency in reading comprehension, vocabulary development, grammar awareness or their own personal definition. For the quantitative component, Ratan applied the New York City Department of Education's definition of literacy, which designates scores of 3+ as proficient and 1–2 as below proficiency. Ratan used publicly available DOE ELA score data for all schools to create an excel spreadsheet correlating the availability of Latin instruction at a particular school to the percentage of students performing at or above a Level 3 on ELA assessments. Ratan stored all of his findings, both qualitative and quantitative, in a publicly accessible website. Ratan is both grateful and proud to have been able to learn from and contribute to the ongoing effort to improve youth literacy in NYC public schools through a more unconventional approach.

Shea Rathburn CC'26, Creative Writing, History

Faculty Mentor(s) or Supervisor(s): Maleda Belilgne
Title: Absences of the Archive: Finding Female Impersonation in the Queer Harlem Renaissance

Abstract: The Harlem Renaissance was marked not only by an explosion of performance and art by Black creatives, but by queer performances, art, and relationships as well. Female impersonators and drag queens were integral parts of this queer Renaissance, including the Sepia Gloria Swanson, who was labeled "the queen of Harlem," and made appearances in clubs across the country, including some of Harlem's most well-known clubs and cabarets, such as the Theatrical Grill and 101 Ranch. When reading about her life through primary sources, advertisements about her performances in Black newspapers across the country are the main archive we have of her life. After her death at age forty, her name has become much more unknown by many today. Swanson is just one of many of these Harlem Renaissance figures that we broadly consider part of the queer Harlem Renaissance, due to their same-sex relationships and gender non-conforming behavior. Drag and the art of female impersonation by individuals like Swanson have received far less attention for their role in the Harlem Renaissance, in spite of their huge presence both onstage and off. This research paper explores Sepia Gloria Swanson as a potentially transfeminine individual, and asks questions about how we, as historians, can investigate threads of her life in the archive and the power of the archive as a result. What is the role of spectacle in archival documentation of Black queer lives, especially when most of what we have are newspaper advertisements? How can we create a historical narrative about an important queer figure like Swanson with these ephemeral remnants of her life? And, how can we do so in a respectful, ethical, and conscious way?

Patrick Rivas-Giorgi CC'28, Biochemistry

Faculty Mentor(s) or Supervisor(s): Victor Batista
Title: StrategicDiversity: A new metric for evaluating diversity of computer-generated synthetic routes

Abstract: Computer-aided synthesis planning (CASP) is the use of programs to aid in the design and synthesis of molecules by generating possible chemical pathways, i.e. series of necessary reactions for making target molecules in the lab. These tools are especially important for drug discovery, and recent advances in generative AI have greatly expanded their capabilities and the number of different tools being created. Various metrics exist to evaluate these tools, such as the average number of generated pathways for a given set of targets or the number of targets for which a possible pathway was discovered. Another helpful attribute a pathway prediction tool may possess is diversity, which is difficult to exactly define, but can be conceptualized as the "creativity" of a model, the ability to come up with a greater number of substantially different strategies to synthesize a compound. Previous methods have been proposed to measure this difficult-to-quantify metric, but are often very restrictive or do not take chemical intuition, like bonds breaking and reconnecting, into account. Our new metric, StrategicDiversity, takes advantage of the work of recent machine learning methods to implement a new metric that identifies the "higher-level" strategies contained within a set of synthetic pathways. The program identifies important bonds formed in reactions and the atoms involved, abstracting the chemical strategies among the minutiae of specific chemical reactions. Our metric provides synthetic chemists and model designers with a more chemically-interpretable measure of diversity.

Yordani Rodriguez CC'28, American Studies

Faculty Mentor(s) or Supervisor(s): Brian Luna Lucero
Title: Border Bodies: How Borders Shape and Are Shaped by the Body

Abstract: This paper examines the immigrant body as both a physical reality and a metaphor within what the author calls border culture. In recent years,

immigration arrests in the United States have surged, threatening not only the physical safety of immigrants but also shaping how immigrant bodies are perceived and treated. Border culture, as developed in the work of Gloria Anzaldua, describes a state of in-betweenness where immigrant lives are marked as foreign, suspect, and subject to removal. This essay extends that idea by exploring how the body itself can be understood as a border: it is enclosed by skin, organs, and cells, while also interacting continuously with its environment. Drawing on philosophical accounts of the body from Michel Foucault, Judith Butler, and Shannon Sullivan, the paper argues that immigrant bodies are not passive objects of law and policy but active, dynamic participants in the creation of culture. They both shape and are shaped by the borders they encounter. By framing the immigrant body as transactional—always merging, bleeding, and reforming—the author shows that border culture is not confined to physical lines on a map but is lived daily in the spaces where immigrants work, move, and survive. This approach reveals that the immigrant body is simultaneously endangered and agentic, vulnerable to state power yet essential in forming new ways of belonging and resisting exclusion.

Alex Rosen CC'28, Computer Science

Faculty Mentor(s) or Supervisor(s): Adam Reich
Title: The Impact of Communities Groups on Incarcerated Individuals' Rule Violation Rates

Abstract: Solitary confinement is often criticized as being one of the most cruel punishments utilized by the U.S. Criminal Justice System. In it, individuals are deprived of human contact and, as a result, can develop disorders that prevent them from reintegrating into society. This study seeks to establish whether the opposite of that punishment might therefore have the opposite effect. Specifically, it examines the effect of community groups in prisons — such as religious or educational groups — on rule violation rates. This study conducts a logistic regression of almost 14,500 entries from the Bureau of Justice Statistics' "Survey of Inmates in State Correctional Facilities" and adjusts them for confounding variables such as race, age, sex, facility ID, and others. It finds that while involvement in community groups such as education and religion leads to a statistically significant ($p<0.05$) increase in rule violations, it is also correlated with a decrease of violent rule violations (albeit with a less significant p -value). While there are certain limitations to this study, namely not being able to control for how long an individual has been a part of a community group or when their rule violation was committed, its findings do suggest that communities can be a useful method for reducing violent rule violations and a powerful policy tool for enacting such change.

Melina Rozehkhan GS'26, Political Science

Faculty Mentor(s) or Supervisor(s): Tamar Mitts
Title: From Tunisia to Iran: The Role of Women in Shaping Protest and Democratic Transition

Abstract: In 2022, the death of Mahsa Amini, a 22-year-old woman arrested for not adhering to Iran's mandatory hijab laws, ignited the Women, Life, Freedom movement. It became one of the largest waves of protest in Iran's recent history against state violence, gender repression, and authoritarian rule. More than a decade earlier, Tunisia's 2011 revolution during the Arab Spring ushered in the region's first democratic transition, after nationwide protests against unemployment, corruption, and repression. This project compares these two landmark movements to investigate how gender and women's participation shaped the protests' trajectories, and why Tunisia moved toward democratization while Iran did not.

The study focuses on four core themes: the gendered nature of state repression, the ways women assert political agency under authoritarian rule, the role of social media in amplifying female-led resistance and building transnational solidarity, and the intersection of gender, religion, and human rights. Methodologically, it combines qualitative content analysis with a comparative case study approach, drawing on protest slogans, social media posts, photographs, oral histories, and international media coverage, complemented by interviews with activists and experts.

By centering women's voices, this project aims to identify the strategies that made protest participation more effective in Tunisia than in Iran and to shed light on how gender reshapes the possibilities of political change. In doing so, it contributes to understanding how women's mobilization can both challenge authoritarianism and pave the way for more inclusive democratic futures.

Benjamin Rubin CC'27, Physics

Faculty Mentor(s) or Supervisor(s): Maryam Barzegar
Title: Vertical Graphene Josephson Junction
Abstract: A Josephson Junction (JJ) is a quantum device made of two superconductors separated by a thin non-superconducting barrier called a weak link. The defining Josephson effect states that a phase difference between the superconducting electrodes drives a supercurrent across the weak link—no applied voltage necessary. This current-phase relationship is nonlinear, giving rise to anharmonic energy levels that make JJs fundamental

elements of superconducting quantum circuitry. This project's aim is to fabricate a vertical JJ with ultrathin graphene serving as the normal metal weak link between aluminum superconducting electrodes. Most graphene-based JJs use an easily-reproducible planar geometry, where current flows laterally across a lithographically-defined gap. However, this geometry is limited to electrode separations of ~30 nm and suffers from edge disorder. By contrast, a vertical design sandwiches the graphene between top and bottom electrodes, reducing the junction length to the graphene thickness—ideally a single atomic layer, 0.4 nm. This geometry improves electrode-barrier transparency, enhances superconducting coherence, and offers a new pathway for exploring atomic coherence phenomena. To realize the junction, the bottom electrode was patterned onto a silicon chip and sputtered with titanium, aluminum, and platinum. Mechanically-exfoliated graphene flakes were identified and transferred onto the electrode using a PDMS/PPC stamping method. After residue removal, the top aluminum electrode was patterned and deposited, completing the vertical junction. When cooled below the superconducting transition temperature, these devices drive highly-coherent supercurrent through the graphene and display the nonlinear, anharmonic behavior essential for applications in qubits, particle detectors, superconducting electronics, and more.

Dyahatou Saanon SEAS’27, Mechanical Engineering, Nina Rampon Zamith SEAS’27, Civil Engineering

Faculty Mentor(s) or Supervisor(s): Huiming Yin
Title: Refining Cellulose Aerogels: Toward Next-Generation Materials for Energy Efficiency

Abstract: Cellulose aerogel is a high performing material used in many engineering applications, with particular interest for HVAC applications as a result of their low thermal conductivity, transparency, and other mechanical properties that promote energy efficiency, whilst also offering potential for materials that are both functional and visually appealing in infrastructure. This work builds on prior studies of transparent and flame-retardant aerogels, seeking to replicate and refine the production process of silica/cellulose composite aerogels. The preparation method and resulting structural properties of cellulose aerogels are dependent on their respective cellulose concentrations, measured by weight percentage of cellulose (wt%). This study thus investigated the effects of varying cellulose concentrations on key properties such as transparency and structural integrity. Four successful cellulose aerogels were synthesized through a three-step process: cellulose dissolution, gel formation through a chemical process that creates a stable network, and drying of the resulting gel. These results demonstrated that optimizing cellulose concentration was critical for balancing transparency and structural integrity; samples with lower cellulose content (below 3 wt%) exhibited the highest transparency. Overall, this provided valuable insights for tailoring cellulose aerogels for applications requiring transparent and structurally robust materials. Future work will focus on refining drying methods and improving reproducibility.

Karan Saini CC’26, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Oliver Hobert
Title: Role of VAB-15 homeodomain transcription factor in specifying neuron identity in the C. elegans nervous system

Abstract: Terminal selector-type transcription factors specify and maintain neuron identity in C. elegans, where homeodomain transcription factors, encoded for by homeobox genes, are over enriched as terminal selectors. Although most neuron classes in C. elegans have experimentally-validated terminal selectors, there remain neurons for which no known terminal selector has been identified. Notably, these include PVQ, a glutamatergic interneuron in the lumbar ganglion, and PVT, a peptidergic interneuron in the pre-anal ganglion that post-mitotically functions to keep the ventral cord fascicles intact. The vab-15 homeobox gene displays elevated mRNA transcript in PVQ and PVT compared to other neuron classes. Additionally, the VAB-15 homeodomain transcription factor already acts as a terminal selector for the M5 pharyngeal neuron and previously characterized vab-15 mutants display a loss of the sra-6 PVQ terminal fate marker. However, the role of VAB-15 as a candidate terminal selector for PVQ or PVT has not been fully explored. To address this open topic, strains possessing complete knock-out alleles of vab-15 were sourced or generated via CRISPR/Cas9 genome engineering in the background of fluorescent reporter alleles for PVQ and PVT marker genes. Compound and confocal microscopy were used to analyze the expression of PVQ and PVT markers in vab-15 wildtype and mutants. Current results indicate that vab-15 is unequivocally expressed in the M5, AVG, PVC, PVQ, and PVT neurons, as per a vab-15 CRISPR reporter. Vab-15 knock-out exhibits no effect on acr-5 and flp-26 driven expression of the mTagBFP2 NeuroPAL landmark fluorophore in PVQL/R. Moreover, vab-15 knock-out appears to have no effect on lim-6 promoter driven expression of the CyOFP1 and mNeptune2.5 NeuroPAL landmark fluorophores, nor the acr-5 promoter driven expression of the mTagBFP2 NeuroPAL landmark fluorophore in PVT. Provided that vab-15 knock-out affects the expression of PVQ and PVT markers, the identification of VAB-15 as a terminal selector for PVQ and/or

PVT will contribute to the growing repository of master regulators of the C. elegans nervous system.

Jacques Sangwa CC'28, Political Science, Public Health

Faculty Mentor(s) or Supervisor(s): Lawrence Brown
Title: Vaccine Policy and History of the United Kingdom: An analysis

Abstract: My research sought to understand how the United Kingdom (UK) maintains vaccine uptake without legalizing vaccinations. This study examined UK vaccine history, rates of trust in vaccinations, and solutions to the current concerns regarding vaccine uptake. I conducted this research because I was interested in why the UK chose this system and how it has functioned thus far. In a time where healthcare has become politicized and regulated vaccinations are threatened, this research is crucial so that we know how other countries have used autonomy to improve health. Surprisingly, I found that vaccine uptake in the UK has decreased in recent years. Reasons include anti-vaccine sentiments within the media, NHS communication failures and inaccessible vaccination resources, specifically for immigrants. Despite these concerns, I also found there are solutions in progress to these problems like decreasing vaccine hesitancy, tailoring interventions to specific communities and resolving accessibility and communication barriers for citizens. In UK history, giving people the tools and knowledge to make informed decisions lead to the highest form of autonomy over their health. However, these tools are no longer enough. The next step is to communicate with the scholars and professionals engaging in the field of vaccination policy and uptake in the UK. With political tensions growing daily and new populations appearing in the UK, speaking with those who are watching these trends and dynamics would add to the perspective and depth of my research. I also will share this research at Columbia's Mailman School of Public Health under Professor Lawrence Brown.

Bertha Saucedo CC'28, Climate and Sustainability, Environmental Biology

Faculty Mentor(s) or Supervisor(s): Shannon Marquez
Title: Social Media as a Fundraising Tool for Grassroots Conservation

Abstract: Community-based non-governmental organizations often struggle to maintain a steady flow of donations and grants, particularly when they operate in rural areas. For example, the Gunjur Conservation and Ecotourism Association (CETAG) in The Gambia operates a turtle conservation village to protect the endangered green sea turtle. CETAG relies heavily on ecotourism to support its conservation efforts; however, during slow tourist periods, funding becomes inconsistent and unreliable. Social media provides a novel avenue to connect with local and international supporters, yet few studies have examined its impact on sustaining non-profit organizations. This project examines how social media can be used to raise funds and build awareness for CETAG. The methods include creating official Instagram and TikTok accounts and launching a starter pack of short videos and posts. These materials focus on telling CETAG's story, promoting the importance of turtle conservation, and encouraging donations for the maintenance and expansion of the turtle village. The study resulted in a more widespread international audience and social media engagement, although these efforts did not yield sustainable funding. This project explores how social media can be used as a tool to generate sustainable funding for CETAG and raise global awareness. The methods involve the creation of the social media platforms of Instagram and TikTok, and launching a campaign by creating and posting short videos and fliers of the Sea Turtle Village. This media will focus on promoting the history of CETAG and the importance of turtle conservation to encourage donations for the maintenance and expansion of the turtle village. This study is expected to demonstrate that social media can be used as an affordable tool for rural organizations to generate more reliable funding.

Elan Schonfeld CC'27, Computational Biology

Faculty Mentor(s) or Supervisor(s): Peter Canoll
Title: Identification of Biological Programs Driving Multidrug Responses to MT-125 and Saracatinib Combination Therapy: An Unsupervised Machine Learning Analysis of Single-Nucleus Transcriptomics

Abstract: Glioblastoma (GBM), a highly aggressive brain cancer, remains one of the most dangerous and difficult to treat tumors. We tested the ability of MT125, a newly developed non-muscle Myosin II inhibitor, combined with Saracatinib, an oncogenic signaling inhibitor, to treat 2 GBM subtypes with growth-promoting gene amplifications. Tissue specimens collected from GBM patients intraoperatively were sliced and treated ex-vivo with: i) control (DMSO), ii) MT125, iii) Saracatinib, or iv) MT125 + Saracatinib, followed by single-nucleus RNA-sequencing for transcriptional analysis. We annotated cell types using marker genes and copy-number variation (CNV): abnormal chromosomal ratios indicative of cancer. Results revealed a region of "hybrid" CNV+ cells expressing both tumor + macrophage markers, defining $\geq$30% of combination-survivor and <2% of control cells per dataset. Next, we compared MT125+Saracatinib-surviving vs. control cells using gene set

enrichment analysis. Synaptic pathways were enriched, while ribosomal assembly/translation pathways were downregulated in combo-surviving cells. Finally, we trained unsupervised machine learning (ML) models to identify subsets of control cells vulnerable/resistant to the combination therapy. Taken together, our findings highlight the success of the MT125 + Saracatinib combination in eliminating tumor cells reliant on traditional survival and energy production pathways, and shift the understanding of GBM viability to a big data-driven atlas of biological resistance programs. Through the discovery of these survival-supporting factors and associated biomarkers with ML-driven diagnosis potential, this work offers a comprehensive strategy to overcome the challenges of aggression and resistance in glioblastoma, offering hope for a new era of progress in targeted therapies and patient care.

Remi Seamon CC'26, Comparative Literature

Faculty Mentor(s) or Supervisor(s): Angela Koćzé
Title: Repoliticizing Reproductive Justice in Neo/Colonial Europe

Abstract: The term "reproductive justice" was first coined by Black feminists in the US as a way to describe the unique challenges faced by women of color concerning bodily autonomy and racialized reproductive control, which manifest in forced or coerced sterilization, delegitimization of parental rights, and a lack of safe environments in which to raise children. They sought to bring awareness to these issues since mainstream debates about reproductive rights continue to center on the ability of women to terminate or prevent unwanted pregnancies, and not the right to safely and humanely bear and raise children. Romani peoples are a racialized population who face similar challenges, particularly in Eastern Europe. Many scholars explain these two sides of reproductive (in)justice through the framework of eugenics, in which the reproduction of "desirable" populations is encouraged (resulting in restriction of access to abortion and contraception for what is usually white, middle-class, able-bodied women) and the reproduction of "undesirable" populations is discouraged through measures of forced or coerced sterilization, disproportionate contraceptive campaigns, and as culminated under the Nazi regime, murder. However, explaining the forced sterilization of Romani women purely through the framework of eugenics ignores the fact that eugenics was only a recontainment of past systems of racialized control—those of generational enslavement, imperialism and colonialism. A study of the roots of forced sterilization of Romani women illuminates the complex intertwining of diverse systems of oppression otherwise treated separately, as well as the transnational nature of racialized reproductive control. Moreover, bringing to light the history of Romani peoples in Europe acts as a bridge between Europe's external practices of colonization, and internal.

Nima Sedghi GS'27, Biological Sciences

Faculty Mentor(s) or Supervisor(s): Jellert Gaublomme
Title: Investigating the Regulation of Mitochondrial Morphology and mtDNA

Abstract: Mitochondria play crucial roles in the cell, from generating ATP to involvement in cell death (apoptosis), and a major part of these functions are regulated by mitochondrial DNA (mtDNA). However, despite mitochondria's critical functions, there are no screens that focus on mtDNA and its relationship to mitochondrial morphology. Our study attempts to fill in this gap by using genetically designed human cells that express necessary enzymes for gene editing. Using a specific type of gene editing developed by our lab called CRISPRmap, we generated a pool of 2372 different guides that target nuclear-encoded genes known to be associated with mitochondrial functions or encode proteins located in/near mitochondria. These guides approximately target 1100 different nuclear-encoded genes, and each cell will present only one gene knockout. We would then perform genotype-phenotype analysis using training modules that are created for the computers to be able to make necessary calculations and generate the data to confirm the existing data and find new genes that result in unknown phenotypes. From these findings we will generate the gene of interest list and perform different experiments to understand their full function. Some of these experiments include mitochondrial functional analysis, live cell imaging, monitoring mitochondria-endoplasmic reticulum contact sites (MERCs), and additional antibody staining for high-resolution imaging. We establish the effect of each gene on the phenotype of the cell and identify the intermediaries at play. This study aims to find the relationship between genotypes and phenotypes in mitochondria, mtDNA, and their relationship to other organelles.

Diya Shah CC'28, Neuroscience

Faculty Mentor(s) or Supervisor(s): Michael E. Goldberg
Title: The Role of the Cerebellum in Learning and Motor Control: Training Behavioral Responses in Rhesus Macaques

Abstract: The cerebellum is widely known for coordinating movement, yet increasing evidence shows it also contributes to learning and decision-making. This project investigates how the cerebellum merges these functions by training a rhesus macaque to perform a visual decision-making task. In the task, the monkey sees one of two images and must lift its left hand for one

image and its right hand for the other. Across repeated practice sessions, the animal undergoes an extended learning process in which performance steadily improves, forming a clear behavioral learning curve. This curve reflects the gradual strengthening of visual-motor associations, as the monkey becomes faster, more accurate, and more consistent in its responses. To probe the cerebellum's role directly, electrodes are placed in a specific region while the task is performed. Once the initial associations are mastered, the contingencies are reversed, requiring the monkey to learn new rules for the same images. During this reversal, the animal again shows a systematic learning curve marked by errors that gradually give way to stable, correct performance. Importantly, cerebellar recordings reveal changes in neural activity that track both the acquisition and the reversal of the associations. These findings highlight how the cerebellum links memory and motor control, providing insights into the neural basis of adaptive behavior.

Liv Shalom GS'26, Chemical Physics

Faculty Mentor(s) or Supervisor(s): Dmitri Basov
Title: Near-Infrared Lithography with $MoOCl_2$

Abstract: This project explores a new method for creating patterns on the nanoscale by using a special layered crystal called molybdenum oxychloride. This material can trap and guide light in unusual ways, forming tightly confined waves that generate repeating light patterns smaller than the wavelength of the light itself. These patterns, known as fringes, have the potential to be used in advanced forms of lithography—processes that define very small structures on surfaces, such as those used in microelectronics and nanotechnology. The focus of the project is to test whether these light patterns can be captured using photoresists: light-sensitive materials commonly used in chip manufacturing. The study investigates whether the strong light fields created by the crystal can trigger a response in photoresists exposed to near-infrared light between 1-2 micrometers in wavelength. Using a laser that produces extremely short pulses of light, researchers generate these patterns, apply photoresist materials like SU-8 and IP-Dip, and observe whether any chemical changes occur in the coating.
The goal is to determine if it is possible to record these nanoscale light patterns without using traditional optical lenses, relying instead on the natural properties of the crystal. The findings could open new paths for nanofabrication, combining insights from chemistry, physics, and materials science.

Trisha Sharan CC'27, Environmental Science

Faculty Mentor(s) or Supervisor(s): John Hildebrand
Title: Using Passive Acoustic Monitoring to Characterize Odontocete Habitat off of the Antarctic Peninsula

Abstract: Passive acoustic monitoring is a crucial tool for understanding cetacean distribution, especially for elusive species, such as many toothed whales, or odontocetes, that are infrequently sighted due to their deep-diving foraging behavior. The Western Antarctic Peninsula is experiencing high rates of climate change, potentially shifting ecosystem dynamics. Seasonal sea ice cover makes the region inaccessible to shipboard surveys for much of the year, making it an ideal candidate for passive acoustics. High-frequency Acoustic Recording Packages (HARPs) were deployed at three sites near the South Shetland Islands from 2014 to 2016 and acoustic data was analyzed for presence of sperm whales (Physeter macrocephalus), killer whales (Orcinus orca), long-finned pilot whales (Globicephala melas), southern bottlenose whales (Hyperoodon planifrons), and Mesoplodon sp. beaked whales (BW58 and BW37 click type). The South Shetland Islands are characterized by strong oceanographic gradients where the Antarctic Circumpolar Current interacts with shelf waters, generating fronts and eddies that influence prey availability for top predators. Oceanographic model and satellite data were used to quantify environmental drivers (temperature, salinity, primary production, sea ice cover, etc.). Generalized Additive Models (GAMs) were constructed to assess habitat preference of each species. Several species had significant relationships with and clear preferences for sea surface temperature, primary productivity, and mesoscale features. All species were found to be ice-avoidant and were rarely present during austral winter, confirming previous hypotheses about their habitat. These models develop understanding of odontocete ecology, creating a baseline for monitoring ecological responses to rapid climate change in the Southern Ocean.

Anvesha Sharda SEAS'28, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Scott Fan and Jing Ding
Title: DAPT Inhibition of DLL4–Notch1 Signaling Slows Tumor Cell Migration in a Surgical Wound Model

Abstract: Cell migration, particularly in the context of wound closure dynamics, is central to tumor metastasis and mechanobiology. Yet the signaling pathways that govern migration, such as the Dll4–Notch1 leader–follower mechanism, remain underexplored in cancerous epithelia. Even less is known about their role following mechanical wounding, such as that modeled by the scratch assay. Because surgical tumor removal itself can

contribute to recurrence by leaving behind residual cancerous cells and creating wound edges that stimulate migration, this gap is especially important to investigate. To address this, we employed a scratch-wound assay in HeLa monolayers to characterize wound closure dynamics and compare them to patterns observed in noncancerous epithelia. We also tested the dependence of migration on Dll4–Notch1 signaling by disrupting the Dll4-Notch1 contact chain. Pharmacologic inhibition with the γ-secretase inhibitor DAPT impaired wound closure, slowing migration by nearly 40%. Immunostaining confirmed upregulation of Dll4-Notch1 at scratch edges, a response hindered under DAPT treatment. These results provide causal evidence that Dll4–Notch1 signaling is required for efficient closure in both cancerous and non-cancerous epithelia, with confluency further modulating this effect and suggesting a dependency on cell proximity for migration efficiency. Our findings reveal that cancerous cells exploit wound-healing pathways normally used by healthy tissues, potentially aiding their spread after surgery. Dll4–Notch1 thus represents a “double-edged sword”: necessary for repair yet permissive for tumor migration. Our results suggest that DAPT has the potential to limit post-surgical cancer spread. Understanding this balance is crucial for strategies that promote healthy healing while limiting cancer recurrence.

Tooli Shariah GS’26, Human Rights, Middle Eastern, South Asian, and African Studies

Faculty Mentor(s) or Supervisor(s): Andrew Nathan
Title: My Best Friend the Goat: Bedouin Bonds with Camels, Goats, and the Art of Survival

Abstract: For Bedouins, survival in the desert has never been a solitary act. It has always been shared—with goats, camels, and other animals that provide food, milk, transport, and even companionship. This project examines the unique human–animal bond within Bedouin communities, demonstrating how goats and camels serve not only as sources of survival but also as friends, teachers, and symbols of resilience. Goats, with their stubborn charm, have sustained families with milk, cheese, and wool while teaching humor and adaptability in the face of scarcity. Camels, often called the “ships of the desert,” are more than transportation—they are companions who endure harsh climates side by side with their human caretakers. Through photographs and personal stories gathered in the Jordanian desert, this research explores how Bedouin families view their animals as integral to the household and even a part of their identity. The project highlights how these bonds reveal an alternative way of thinking about human–animal relationships, not just in terms of utility, but also in terms of friendship and mutual reliance.
At its core, this is a story of survival, laughter, and loyalty—because sometimes, in the desert, your best friend really is a goat.

Angelina Shen SEAS’28, Computer Science, Kevin Wu SEAS’28, Computer Science

Faculty Mentor(s) or Supervisor(s): Huiming Yin
Title: Homogenization of a 2D network

Abstract: The distributions of both electric currents and traffic flows are governed by local conductance and connectivity when they propagate through a 2D network of multiple nodes and links. Although traditional graph-based methods such as Dijkstra’s and A* search algorithms compute shortest paths, they are limited when scaled for dense networks and in providing physical interpretations for multiscale analysis. This paper develops a singum homogenization framework that transforms a discrete 2D network into a Euclidean continuum by partitioning the domain into a Voronoi tessellation. Within each singum, the average flow and potential gradient are defined from edge currents and voltages, leading to an effective conductivity tensor that links the network to continuum partial differential equations. This homogenized formulation enables a direct mapping between the discrete graph and continuum fields, allowing to incorporate bottlenecks, defects, and anisotropy as well. Verification between the finite element solution and Kirchoff’s confirms that the singum model accurately reproduces electric conduction in lattices, including cases with holes or broken links. Extending the analogy to transportation networks, we show how the same framework predicts traffic densities, identifies bottleneck-adaptive routes, and recovers shortest paths through steepest descent of the potential field. Case studies demonstrate its applications to congestion and static routing scenarios, highlighting the scalability and generality of the singum approach. Overall, this methodology offers a physically grounded alternative to heuristic routing algorithms and establishes a unified framework for analyzing flows in electrical, traffic, and other spatial networks.

Alissa Shen CC’27, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Attila Losonczy
Title: Imaging Synaptic Inputs and Tagging Active Synapses in Single CA1 Pyramidal Neurons

Abstract: The formation of spatial memory involves many intricate and highly complex networks in the brain. One such network is called synaptic plasticity, a mechanism of memory that is able to acquire and retain information (Nakazawa, 2004). Within the CA1 region of the hippocampus there are excitatory neurons called CA1 pyramidal neurons that are known to be responsible for the formation of new spatial memories through the development of place cells. These cells are responsible for displaying place fields, which are the spatially and contextually selective receptive fields (Bittner, 2015). While much of the existing literature has characterized the induction of place fields through techniques such as ex vivo brain slices, repeated stimulation protocols, and whole-cell patch clamp recordings (Bittner, 2017), the precise molecular mechanisms underlying the spontaneous formation of place fields in awake, behaving animals remain insufficiently understood. This research project investigates how synaptic inputs to CA1 pyramidal neuron dendrites contribute to place field induction using an all-optical, in vivo approach. This methodology enables us to both monitor changes in synaptic weight and photoactivate specific constructs tagged to the synapse before and after the induction of a place field in single CA1 pyramidal neurons during spatial navigation (Gonzalez, 2024). The main focus of this research will be to discover the specific molecular mechanisms of synaptic plasticity at synapses receiving relevant excitatory input.

Anand Shukla-Parekh GS'27, Philosophy

Faculty Mentor(s) or Supervisor(s): Farbod Akhlaghi

Title: Can Patients Truly Give Informed Consent To Transformative Medical Procedures?

Abstract: Transformative experiences, as conceived by philosopher L.A. Paul, are experiences with two characteristics: (1) prior to actually experiencing them, one cannot know what going through them is like, and (2) going through these experiences changes our outlook, usually through a change in perspective or values. For example, becoming a parent is an experience most cannot truly understand until they become one, and doing so changes most people's values/beliefs. Many medical procedures fall into the category of a transformative experience, such as psychedelic-assisted psychotherapy and gender affirming care. However, this calls into question a patient's ability to give informed consent to these procedures. At face value, it seems that the experiential and outcome-related information necessary to give informed consent are inaccessible prior to the treatment.
This research aims to resolve this bioethical issue, with the goal of understanding how to best secure patient autonomy and well-being during transformative medical procedures. A variety of current literature is referenced and evaluated, along with conceptual analysis of informed consent through consideration of multiple bioethical lenses, such as autonomy and duty of care. This research further clarifies exactly what information patients have access to prior to these procedures. From there, it argues that there is sufficient similarity between the relevant knowledge available to patients undergoing transformative procedures and those undergoing standard procedures. By virtue of this parity argument, while certain precautions must be taken, this research finds there is no ethical issue with administering transformative procedures.

Adam Siemiatkowski CC'28, Chemistry, Mathematics-Statistics

Faculty Mentor(s) or Supervisor(s): Sungho Park

Title: Confinement-Controlled Ligand Binding: Modulation of Phosphine and Phosphite Coordination to Dirhodium (II) Complexes Embedded in Fluorinated UiO-66 Metal-Organic Frameworks

Abstract: Metal-Organic Frameworks (MOFs) have become a promising platform for hosting molecular catalysts due to their high surface area, porosity and crystalline structure. These properties have significant implications in large-scale chemical synthesis as they create the possibility of fine tuning substate-selective reactivity through spatial confinement in pores of varying sizes. In this work, a fluorinated UiO-66 MOF, constructed from Zr_6 nodes and tetrafluoroterephthalate linkers, was post-synthetically loaded with dirhodium(II) tetra-trifluoroacetate [$Rh_2(TFA)_4$], a widely used homogeneous catalyst in C–H activation and other chemical transformations. The coordination equilibria between $Rh_2(TFA)_4$ and a series of phosphine and phosphite ligands of varying steric and electronic properties were examined both in solution and within the MOF framework with ligand binding being tracked through colorimetric qualitative changes, and quantified using diffuse reflectance UV-Vis spectroscopy. Results demonstrate that the synthesized F-UiO-66 selectively suppresses the axial coordination of bulky, strongly sigma-donating ligands (e.g., triphenylphosphine) by up to 3 orders of magnitude, whereas smaller oxygen-containing ligands show minimal suppression. This filtering property of the MOF could be the basis of a promising tactic for blocking catalyst deactivation pathways, extending catalyst lifetimes, and reducing expensive separation steps in industrial chemical reactions.

Alexander Skrypek SEAS'27, Applied Physics

Faculty Mentor(s) or Supervisor(s): Carlos Paz-Soldan
Title: CalcSX™: a lightweight toolkit optimized for analyzing non-planar coils

Abstract: Continuous redesign and iteration of non-planar high-temperature superconducting (HTS) coils for university-scale stellarators, such as the Columbia Stellarator eXperiment (CSX), necessitate fast feedback on magnetic fields and self-induced force calculations. For many CSX prototype coils, heavyweight, license-restricted finite-element workflows are too cumbersome for day-to-day iteration and testing, while ad-hoc scripts seldom provide necessary documentation, validation, user-friendly interfaces, or directly applicable outputs. CalcSX™ addresses this gap with a lightweight, license-free Python toolkit and GUI for preliminary magnetostatics of non-planar coils. The tool accepts parametrized curve coordinates from a CSV file, error corrects ensuring a closed loop, and then uses Principal Component Analysis to orient the coil. Magnetic fields are computed from the Biot-Savart law along user-selected traces. Lorentz self-forces are subsequently evaluated as line integrals along the filament using numerical quadrature. CalcSX™ automatically safeguards against singular self-interaction and ensures practically sampling-invariant totals. Resulting self-force calculations are applied internally using a thin-membrane model based upon user-set HTS tape parameters to provide engineering quantities. CalcSX™ prioritizes reliability and speed on any device, leveraging vectorized kernels, cached segment geometry, progress-aware computation, and a highly configurable numerical methodology. CalcSX™ is not designed as a substitute for complete 3D structural finite-element analysis (FEA); rather, it provides rapid, reproducible checks to inform geometry refinement, winding strategy, instrument validation, and FEA parameters. In application, this accelerates the iterate-fabricate-measure loop, turning raw coil coordinates into physically grounded, engineering-applicable diagnostic estimates within minutes, ultimately bridging the gap between concept optimization and practical HTS coil production.

Caroline Smyth CC'26, Applied Mathematics

Faculty Mentor(s) or Supervisor(s): Graeme Baker
Title: Modeling Capital Distributions via Particle Systems with Rank-Based Births and Deaths

Abstract: This work develops a model of capital distribution in large financial markets that incorporates both the rank-based dynamics of existing firms and the continuous process of entry and exit. Classical approaches like the Atlas model capture the large-scale dynamics of firms - the way stock prices change and their rank interactions - but don't include the entry and exit behavior. To fill this gap, the paper introduces a branching particle system in which each particle represents a firm and evolves according to its rank, while also being created or removed at rank-dependent random times. The rates of these birth and death events are estimated directly from the Center for Research in Security Prices stock database, from which we extract when firms begin and end trading, and map the dates to their market rank at the time. We use Beta distributions to describe the probabilities of entrance and exit at different ranks, which provide the basis for simulating branching dynamics. Simulations show how capital distribution curves evolve when entry and exit are introduced, producing behavior that can't be explained by purely diffusive models.
We are also interested in the mean-field limit as the number of stocks in the market becomes large. Nagasawa (2021) provides a potential partial differential equation to describe the limit that is complicated by the nonlinearity introduced by branching. Del Moral's Feynman-Kac formulae (2004) offers a linear partial differential equation that occurs when only exits, not entrances are present. This framework links empirical event data with theoretical models and offers a new perspective on how market structures may persist despite continual turnover.

Szymon Snoeck SEAS'26, Applied Mathematics

Faculty Mentor(s) or Supervisor(s): Nakul Verma
Title: Compressibility Barriers to Neighborhood-Preserving Data Visualizations

Abstract: To what extent is it possible to visualize high-dimensional datasets in a two- or three-dimensional space? We reframe this question in terms of embedding n-vertex graphs (representing the neighborhood structure of the input points) into metric spaces of low doubling dimension d, in such a way that maintains the separation between neighbors and non-neighbors. This seemingly lax embedding requirement is surprisingly difficult to satisfy. Our investigation shows that an overwhelming fraction of graphs require $d=\Omega(\log n)$. Even when considering sparse regular graphs, the situation does not improve, as an overwhelming fraction of such graphs requires $d=\Omega(\log n/\log\log n)$. The landscape changes dramatically when embedding into normed spaces. In particular, all but a vanishing fraction of graphs demand $d=\Theta(n)$. Finally, we study the implications of these results for visualizing data with intrinsic cluster structure. We find that graphs produced

from a planted partition model with k clusters on n points typically require $d=\Omega(\log n)$, even when the cluster structure is salient. These results challenge the aspiration that constant-dimensional visualizations can faithfully preserve neighborhood structure.

Abigail Song CC'28, Neuroscience and Behavior

Faculty Mentor(s) or Supervisor(s): Aaron Gitler
Title: Investigating the Disease-Causing D252N Mutation in TMEM106B

Abstract: TMEM106B is a lysosomal transmembrane protein associated with the risk and development of various neurodegenerative diseases such as frontotemporal dementia (FTD) and Alzheimer's disease (AD). Structurally, TMEM106B is made up of three domains: a cytosoplasmic N-terminal, a transmembrane region, and a luminal C-terminal domain, which is susceptible to cleavage. Maintaining proper levels of TMEM106B is integral to lysosomal function. However, the mechanisms responsible for its cleavage remain undefined. Recently, a novel de novo point mutation (D252N) in TMEM106B has been found to cause hypomyelinating leukodystrophies (HLD), a genetic, neurodevelopmental disorder characterized by myelin deficiencies. However, it is unknown exactly how this disease-causing mutation affects TMEM106B function and the specific molecular mechanisms behind these effects. To better understand how D252N affects TMEM106B function, we overexpressed TMEM106B constructs with or without D252N point mutation in Human Embryonic Kidney (HEK293T) cell lines. Intriguingly, the D252N mutation reduces TMEM106B overall protein levels and alters TMEM106B C-Terminal cleavage. These findings suggest that the D252N mutation is a potentially impactful modifier of TMEM106B C-terminal cleavage, thereby altering its function in disease.

Tyler Sotomayor GS'27, Economics-Mathematics

Faculty Mentor(s) or Supervisor(s): Hriday Karnani
Title: When the Message Meets the Moment: State-Dependent Effects of Monetary Policy and Information Shocks on the Term Structure of Inflation Expectations

Abstract: This paper examines the state-dependent transmission of monetary policy surprises to the term structure of household inflation expectations, where state dependence arises both from the type of surprise and from whether inflation is supply- or demand-driven. Using horizon-specific inflation expectations from the Federal Reserve Bank of Cleveland and Shapiro's (2024) decomposition of inflation into supply- and demand-driven components, I estimate responses to monetary surprises in a state-dependent local projection framework. Results indicate that pure monetary policy shocks predominantly influence short- and medium-term expectations, whereas central bank information shocks produce broader and more persistent effects across the entire horizon. The magnitude of these responses is amplified under supply-driven inflation regimes and attenuated under demand-driven regimes. These findings reveal that the credibility and effectiveness of monetary policy are contingent not only on the nature of the monetary innovation but also on the prevailing sources of inflation.

Adam Spree CC'28, Biology

Faculty Mentor(s) or Supervisor(s): Laura Duvall
Title: Meal size regulation and its impacts on fitness in Aedes aegypti mosquitoes

Abstract: Female Aedes aegypti mosquitoes bite humans to obtain nutrients to develop their eggs, making them potent vectors for deadly pathogens. Blood meal size is remarkably consistent across individuals and feeding bouts, but is regulated by an unknown set of chemo and mechanosensory mechanisms. The effects of manipulating meal size on fitness are also not well understood. Previous work has implicated the mosquito ventral nerve cord (VNC) in meal size regulation, likely through mechanosensory pathways. One class of mechanoreceptors expressed in the VNC is the transient receptor potential (TRP) channels, with TRPgamma demonstrating the most specific, robust expression in its receptor class. We investigated a role for TRPgamma in meal size regulation by feeding small-molecule drug compounds previously demonstrated to target human TRPgamma orthologs. By performing this small-scale drug screen, we found that pharmacological manipulation of TRPgamma does not impact mosquito feeding behavior. Separately, feeding mechanoreceptor-targeting drugs known to reduce meal size, we found that small meals result in subsequent changes to reproductive capacity, namely oviposition frequency, clutch size, and hatch rate. These results indicate that reducing meal size through pharmacological mechanoreceptor manipulation could serve as a tool to hinder mosquito reproductive capacity, thereby presenting a novel approach to control infectious disease transmission.

Liam Stiles CC'27, Biochemistry

Faculty Mentor(s) or Supervisor(s): Sam Janes
Title: Understanding Factors that Influence Lung Cancer Screening Participation

Abstract: Lung cancer is a leading cause of death in the United States. Early detection through low-dose computed tomography (LDCT) markedly increases survival by identifying lung cancer at a more treatable stage. This project was completed in conjunction with the SUMMIT study which included a cohort of 12,027 individuals. The aim of this project was to examine how a variety of factors — mainly education, ethnicity, and patient health — influence screening adherence. This project involved interviewing participants to understand their perspectives on these issues. Educational attainment is a significant driver of screening adherence. For example, 86% of postgraduates attended all scans compared with 75% of those with lower educational attainment. Ethnicity was also associated with adherence, with disparities most pronounced among participants with minority status, particularly those with lower education levels. Self-reported health and symptom burden are also strong predictors of screening adherence. Participants with the highest symptom burden had a 71.4% adherence rate compared with 81.6% in those with lower symptom burden. These findings suggest that both educational attainment and perceptions of self-health influence screening participation. Addressing these barriers may reduce disparities and improve early detection rates. To support this goal, a comprehensive educational curriculum was developed covering cancer basics, screening eligibility, benefits, risks, the screening process from appointment to results, and how to discuss screening with a healthcare provider. This resource aims to improve health literacy, build trust in the medical system, and encourage sustained participation in screening programs.

Federico Stock CC’26, History, Philosophy

Faculty Mentor(s) or Supervisor(s): Achille Varzi
Title: Hierarchies of Being: The Structuring of Existence from Augustine to Contemporary Metaphysics

Abstract: In Late Antiquity, both pagan Neoplatonist and Christian philosophers, chiefly Plotinus and Saint Augustine, developed a hierarchically structured ontology. Reality is divided into substantially different levels, which vary according to hierarchical values such as perfection, reality, and simplicity. Between these layers existed dependency, with lower entities exclusively depending on those above them for their existence and eventual blessedness. In this way, for Augustine, does man depend on God, and for the Plotinian school do we depend on the One. These conceptions are intricate, and a fleshing out and comparison of the two reveals their metaphysical detail and central commitments: that there is a hierarchy, that there are a ‘top’ and a ‘bottom’, and that the ‘top’ is metaphysically prior to the ‘bottom’. Contemporary metaphysics inherits a common notion of hierarchy from these ancient conceptions in the notion of grounding—much has remained—but does not align perfectly with them. Such variations are drawn out by a comparison of the formal ontological qualities of the ancient and contemporary theories, as well as their positions on whether metaphysical dependence or grounding are the same or analogous to causation. What is most obviously missing in contemporary metaphysics from the ancient conception is its central view that the whole, which is prior to all else, is simple rather than complex. Furthermore, the hierarchical values that give substance to the hierarchy are not present in contemporary conceptions of grounding, leaving a metaphysics that is indifferent to ethics or theology. A consideration of these absences may bear fruit in developing a theory of an ethics of hierarchy.

Marc Stoyer GS’26, Astrophysics

Faculty Mentor(s) or Supervisor(s): Zoltan Haiman
Title: Extending Comparisons of Non-Gaussian Weak Lensing Statistics Between Baryonic Correction Models and Hydrodynamical Simulations

Abstract: Unlike strong gravitational lensing—whose dramatic arcs and multiple images can be identified visually—weak gravitational lensing leaves only subtle distortions in the shapes of distant galaxies. These statistical distortions, however, carry rich cosmological information, offering a powerful probe of cosmic structure and composition. Unlocking their full potential requires analysis of non-Gaussian statistics, which capture additional information on small, nonlinear scales where baryonic physics remains influential. Modeling these baryonic effects in detail with hydrodynamical simulations is possible but computationally prohibitive at the scale needed for cosmological inference. This project utilizes the baryonic correction model (BCM) introduced by Aricò et al. and extends upon the findings of Lee et al. by exploring a wider suite of non-Gaussian statistics. Using an adapted pipeline, baryon-corrected versions of IllustrisTNG dark matter only (DMO) simulations are generated and compared directly to their full hydrodynamical counterparts. This framework aims to evaluate statistics such as peak and minima counts, Minkowski functionals, and higher-order moments, with an emphasis on whether particular parameter choices can jointly reproduce multiple measures rather than being tuned to one in isolation. By determining the accuracy and utility of current era BCMs for weak lensing, this work aims to improve cosmological parameter inference in next-generation surveys such as LSST, Roman, and Euclid.

Abigail Sturley CC'27, Climate System Science

Faculty Mentor(s) or Supervisor(s): Jerry McManus
Title: Holocene Changes in the East Basin of the Deep Atlantic Ocean

Abstract: With the threat of rising temperatures, the Atlantic Meridional Overturning Circulation (AMOC) has been predicted to slow down or stop entirely, potentially exacerbating climate dysregulation in the Atlantic region. This project looks to the geologically recent past, to examine how much and in what way Atlantic ocean circulation has fluctuated over the last ~10,000 years. From IODP expedition 397, we processed 33 samples from site 1586, the sediment core at the greatest depth from the Iberian Margin. Stable isotope analysis of benthic foraminifera microfossils found in these sediment cores is a widely used technique for reconstructing past ocean circulation patterns; δ13C is a tracer for water masses, and δ18O is a proxy for sea temperature and land ice coverage. We searched specifically for Cibicidoides wuellerstorfi foraminifera and used mass spectrometry to find their values of δ13C and δ18O throughout the time-series. Our analyses of the stable isotopes generally indicate a warm climate and strong AMOC activity throughout the Holocene. Within the time interval 3.5-2.4 ka, stable oxygen isotope analysis shows a deep water temperature change from warmer to colder conditions. The lowest δ13C value occurs within that time interval; after δ18O values dropped at 3.5 ka, and gradually started increasing, the δ13C decreased significantly at 2.8 ka. The fact that the lowest δ13C value coincides with a 1,000 year period of deep water temperature change shown in the δ18O record suggests a link between climate change and AMOC activity in the past, and supports predictions for the impact that current climate change may have on AMOC in the future.

Tiffany Suen CC'28, Mathematics, Physics

Faculty Mentor(s) or Supervisor(s): Kishalay De
Title: Carbon-rich Extremely Long-period AGB Stars: NIR Spectroscopy and Implications for Stellar Evolution

Abstract: Low- and intermediate-mass stars reach the final stage of their lives on the Asymptotic Giant Branch (AGB), where they pulsate with periods ranging from several hundred to over one thousand days. Stellar evolution models predict that only stars with initial masses between roughly 1.4 and 3.2 times the mass of the Sun can bring carbon from their cores to their surfaces, producing carbon-rich stars. Lower-mass stars remain oxygen-rich because they cannot produce enough carbon, while higher-mass stars convert carbon into oxygen before it reaches the surface. This project analyzed how stars vary in brightness using data from the Palomar Gattini-IR (PGIR) time-domain survey and identified eight AGB stars with pulsation periods exceeding 1000 days. Follow-up observations with near-infrared spectroscopy at the NASA Infrared Telescope Facility (IRTF) revealed that three of these extremely long-period stars are carbon-rich. According to stellar evolution models, stars with such long periods should be too massive to become carbon-rich. These findings challenge existing models of stellar evolution, suggesting that some stars can become carbon-rich at higher masses or longer periods than previously thought. The discovery highlights gaps in theoretical models and provides new targets for studying the late stages of stellar evolution in more detail.

Jeremy Switzer GS'26, Archaeology

Faculty Mentor(s) or Supervisor(s): Zoe Crossland
Title: Preliminary archaeobotanical results from fieldwork in highland Madagascar

Abstract: Highland Madagascar is characterized by its landscapes of intensive wet-rice production. Rice plays a central role in local diets and in social and political imaginaries. However, little is known about the history of other crops grown in Madagascar. This poster presents some of the earliest examples of legumes recovered from highland Madagascar. The remains presented here come from the site of Ambohidahy (alt 1400m). Occupied throughout the 15th century it was settled as part of a wider regional movement of communities up onto the higher ground. The settlement is located on a low hilltop, encircled by deep ditches. Nearby is a high spring and small pond and associated reservoirs. Excavations in the deeply stratified midden deposits of the south side of the site have produced a range of archaeobotanical materials form the early 15th century, characerized by wetland taxa and legumes. So far, no rice grains have been found in the earliest levels of the site, despite offsite evidence that rice was being grown locally.

Parsa Talaie CC'27, Applied Mathematics

Faculty Mentor(s) or Supervisor(s): Elias Issa
Title: Comparing Marmoset and Macaque Ventral Streams with Deep Neural Networks

Abstract: The ventral stream is a part of the primate visual system used for high-level behaviors such as object recognition. Neural activity in this area encodes information such as object identity, lighting, and background,

particularly in deeper areas. Most research on the ventral stream has used macaque monkeys, but in recent years the marmoset has emerged as a smaller, more cost-effective model. However, it is unclear whether the marmoset's visual system is as sophisticated as the macaque's. The primary method of investigations into high-level primate vision has been with deep neural network models (DNNs), which have been shown to be the most accurate models in predicting the ventral stream response to various images. In prior work, if DNNs with more sophisticated training and architecture are more predictive of the activity in a visual system, that visual system is considered more sophisticated. This work compares the predictivity of DNNs used in macaque studies to evaluate the capacity of the marmoset visual system. It was found that, similar to the macaque, trained self-supervised DNNs consistently outperform randomized and supervised models across multiple metrics, monkeys, and imagesets. However, the average predictivity across models is lower in the marmoset by ~13%, and the differences in predictivity between models are slightly lower as well. This research suggests that the marmoset ventral stream is nearly as advanced as that of the macaque, possibly allowing for more cost-effective research into high-level primate visual behavior in the future.

Jishnu Talukdar CC'28, Biochemistry

Faculty Mentor(s) or Supervisor(s): Seung Kim
Title: Targeting Genetic Roadblocks to Mature Stem Cell-Derived Beta Cells for Diabetes Therapy

Abstract: Diabetes is driven by the dysfunction of pancreatic beta cells, the body's source of insulin. Current treatments, including insulin injections and artificial pancreas devices, manage symptoms but do not restore the body's natural ability to regulate blood sugar. Islet transplantation offers a potential cure, yet it is limited by immune rejection, poor survival of transplanted cells, and the immature state of stem cell-derived beta cells. This project seeks to address the final challenge: functional immaturity. Using human embryonic stem cells, MEL-1 hESCs were guided through developmental stages that mimic how beta cells form in the embryo. While these protocols reliably produce insulin-positive cells, the resulting cells behave more like fetal precursors than adult beta cells. To overcome this "maturation wall," genetic factors that may restrict full functionality were investigated. By applying lentiviral shRNA knockdown to reduce the activity of specific genes, silencing "immaturity markers" were tested to see if they could shift cells toward a more adult-like state. Initial experiments targeted the gene FEV, which is active in immature populations. Knockdown of FEV altered the expression of several endocrine genes, including glucagon, suggesting it influences lineage balance within developing islet cells. A second candidate, LMX1B, is currently under investigation. Together, these findings indicate that modulating transcription factors may help guide stem cell-derived beta cells toward functional maturity, improving their therapeutic potential. Ultimately, this research aims to advance stem cell-based cures for diabetes.

Kah Sin Tang GS'26, Evolutionary Biology of the Human Species

Faculty Mentor(s) or Supervisor(s): Dustin Rubenstein, Frane Babarović
Title: Rainbows in a Feather: Structural Color and Iridescence in the Wing and Breast Plumage of Superb Starlings

Abstract: This project explores structural coloration in the plumage of the superb starling (Lamprotornis superbus), focusing on iridescent features in wing and breast feathers across multiple years. Iridescent structural colours are produced by the nanoscale arrangement of melanosomes in feather barbules. While the mechanisms of their production have been widely studied, their susceptibility to environmental conditions has been largely overlooked. To address this knowledge gap, we used spectrometry to quantify iridescent plumage coloration at three locations within a patch (back) and at four locations within a single feather (wing feather). For both experiments, we collected measurements from five individuals across 13 years (2009–2021). Results will be visualized in R by plotting reflectance curves, from which colorimetric variables (brightness, hue, and chroma) will be extracted, both between plumage patches and within single feathers. By comparing measurements across multiple years and correlating them with environmental conditions, we will assess whether any of the colorimetric variables change in response to environmental variation, either at the level of a plumage patch or within a single feather. This work not only contributes to understanding avian coloration but also provides a framework for linking feather coloration to ecological and broader evolutionary processes.

Hyatt Taylor CC'27, Environmental Biology

Faculty Mentor(s) or Supervisor(s): Jennifer Merritt
Title: Discovering the molecular basis of glucocorticoid evolution within Peromyscus

Abstract: In order to better understand the evolution of behavior—most notably pair bonding, parental care, and exploratory behavior—we must examine the function of glucocorticoids, which are strong candidates for driving behavioral evolution. Peromyscus is a unique genus because of its behavioral variability across species in pair bonding, exploratory behavior, and parental care. The two species of interest, oldfield and deer mice, are sister species that diverged from a common ancestor about 2 million years ago, yet they exhibit significant behavioral differences. Oldfield mice are known to be monogamous, exploratory, and biparental, whereas deer mice are polygamous, risk-averse, and exclusively maternal in their care. To determine the molecular basis of these behaviors, corticosterone is investigated as a possible contributor, as oldfield mice have about ten times higher plasma corticosterone concentrations than deer mice. Contrary to the expectation that oldfield mice would be the exception within Peromyscus evolution, deer mice appear to have blunted corticosterone circadian rhythms and desensitized baseline corticosterone regulation compared to other Peromyscus subspecies. Differences in a biological regulator, CBG, have also been detected between deer and oldfield mice, suggesting that more than one immunological regulatory system influences behavior. There is still more to learn about regulatory CBG and the biological precursor ACTH within Peromyscus subspecies, as well as whether the evolution of the glucocorticoid receptor contributes to species differences in pair bonding, parental care, and exploratory behavior.

Abbey Tessema CC’28, Biochemistry

Faculty Mentor(s) or Supervisor(s): Renee Read
Title: Targeting YAP/TAZ-TEAD–AXL Signaling to Remodel the Tumor Microenvironment in Vestibular Schwannoma

Abstract: Vestibular Schwannoma (VS), accounting for approximately 6% of all intracranial tumors in the United States, affects over 3,000 patients annually. Arising from the Schwann cells of the vestibulocochlear nerve, VS is typically benign but can cause sensorineural hearing loss, facial nerve dysfunction, and brainstem compression. Current treatment modalities such as surgical resection and radiotherapy, often fail to preserve hearing, underscoring the need for novel targeted therapeutic strategies.
Emerging data implicate dysregulation of the YAP/TAZ pathway in VS. AXL, a receptor tyrosine kinase and downstream effector of YAP/TAZ-TEAD, as well as phosphorylated ERK are frequently upregulated in VS and may modulate the tumor microenvironment (TME) as well. We hypothesize that pharmacologic inhibition of YAP/TAZ-TEAD and AXL signaling will alter the VS tumor microenvironment by reducing cellular stemness and immune infiltration. To test this, we investigated the molecular and cellular consequences of YAP/TAZ-TEAD–AXL signaling in VS using ex vivo pharmacologic perturbation and immunostaining. Additionally, the expression of AXL and YAP was evaluated alongside neural stem cell markers (Nestin) to characterize the TME. Quantitative image analysis using QuPath enabled high-throughput cell segmentation, positive cell detection, and tissue-area normalization, allowing for robust statistical assessment of TME alterations. Our results suggest that inhibition of YAP/TAZ-TEAD and AXL signaling reshapes the VS tumor microenvironment by reducing stem-like tumor cells and immune cell expression. These findings highlight a previously underexplored therapeutic avenue and support further investigation into Hippo pathway–targeted agents to improve outcomes in VS. Ongoing studies aim to validate these results and further advance efforts toward precision medicine and hearing preservation in patients with VS.

Harini Thiruvengadam CC’27, Biology

Faculty Mentor(s) or Supervisor(s): Hashim Al-Hashimi
Title: Disrupting HIV-1 Transactivation with RNA-Targeted Small Molecules

Abstract: Despite decades of progress in antiretroviral therapy, HIV remains incurable, with latent reservoirs and drug resistance limiting long-term success. Here, we investigate an RNA-targeted strategy that blocks viral transcription at its earliest step by disrupting the interaction between the trans-activator of transcription (Tat) protein and the transactivation response (TAR) RNA element. To overcome the challenges of targeting TAR’s dynamic structure, our lab used ensemble-based virtual screening (EBVS) to identify small molecules predicted to bind TAR across its conformational ensemble. We then used a three-part experimental approach to evaluate the top candidate compounds: 1) in-vitro fluorescence based displacement assays; 2) a luciferase reporter assay in HEK293T cells to evaluate transcriptional disruption; and 3) NMR spectroscopy to map structural changes in TAR upon compound binding. Among the EBVS-identified candidates, aminoglycosides netilmicin and neomycin demonstrated promising activity, effectively disrupting TAR-Tat binding. Consistent with these findings, the two drugs bound TAR at key sites and disrupted Tat binding in vitro, as confirmed by displacement and NMR assays. However, netilmicin did not significantly reduce Tat-dependent transcription in the luciferase reporter assay, likely reflecting barriers such as uptake or stability rather than lack of binding. We are currently testing more replicates of netilmicin and neomycin and extending this to other aminoglycosides to better understand what features

drive activity and selectivity. Targeting conserved RNA elements early in the HIV lifecycle may ultimately lead to more durable therapeutics and broaden the potential of RNA-targeted drug discovery.

Mallory Thomas SEAS'27, Earth and Environmental Engineering

Faculty Mentor(s) or Supervisor(s): Shaina Kelly
Title: Characterizing Pore Structure and Permeability Changes due to Microwave Alteration in Low Porosity Granites

Abstract: As high-grade deposits of critical minerals (ex. cobalt, copper, nickel) become increasingly depleted, developing methods to enhance flow pathways for leachate in low-grade ores is vital for advancing more sustainable and economically viable in-situ mining practices. Microwave heating of water-saturated rock offers a potential solution by enhancing porosity and permeability through rapid internal heating and evaporative expansion that generates selective fractures. In this study, eight tight, igneous rock samples were subjected to controlled microwave exposure, alongside a well-studied sedimentary formation that served as a baseline. Porosity and imbibition measurements before and after microwave alteration reveal minor changes in porosity but significant increases in water uptake capacity, a proxy for permeability. Results reveal that Bandera Brown sandstone responds favorably to microwave heating, exhibiting both higher porosity and improved imbibition rates after heating. Granites, some containing pyrite inclusions that react strongly to microwaves, show measurable porosity increases but also complex alterations in permeability pathways. Microwave stimulation therefore emerges as a promising method for enhancing permeability, facilitating the flow of leaching solutions in mineral recovery. This approach could improve extraction of critical minerals from deep, low-grade ores while also supporting applications in carbon storage, geologic hydrogen stimulation, and sustainable oil and gas operations. These findings highlight the impact of microwave heating on tight rock flow capacity as a non-invasive, in-situ stimulation technique towards more sustainable resource extraction.

Anisa Thompson CC'26, Biochemistry

Faculty Mentor(s) or Supervisor(s): Anna-Katerina Hadjantonakis
Title: The Role of SOX2 in Multi-lineage Differentiation in Embryonic Stem Cell Models

Abstract: Studying early mammalian development and pluripotency in vitro requires the generation of embryo-derived cell lines. Mouse embryonic stem cells (mESCs) are derived from the naïve epiblast (Epi), which arises at 4.5 days post-fertilization, and model early embryonic development and gastrulation when cultured under specific conditions. In vitro, mESCs can be differentiated into epiblast-like cells (EpiLCs) and epiblast stem cells (EpiSCs), which parallel the formative Epi at E5.5 and the primed Epi at E6.5 in vivo. SOX2 is a transcription factor that has been implicated in the transition of mESCs from the naïve pluripotent state and may serve as an important regulator of embryonic Epi differentiation. This project seeks to validate preexisting methods for generating pluripotent stem cell (PSC) states and organoid models in vitro using mESCs. Immunostaining and fluorescence for lineage-specific transcription factors was used to confirm successful recapitulation of the embryonic PSC states. A SOX2 degron allele model was used to degrade endogenous SOX2 protein to further elucidate the influence of SOX2 as a director of mESC pluripotency transitions in vitro.

Tata (Chaipat) Tirapongprasert CC'27, Astrophysics

Faculty Mentor(s) or Supervisor(s): Matthew Ho
Title: Eliminating Boundary Pathologies in Simulation-Based Inference via Smooth Parameter Sampling

Abstract: Current neural posterior estimation (NPE) techniques for astronomical inference have lower accuracy near parameter space boundaries due to sharp discontinuities introduced by uniform proposal distributions during training. These boundary pathologies become more problematic in high-dimensional parameter spaces, resulting in posterior estimates that are orders of magnitude less accurate than interior predictions. We present the Tailed-Uniform proposal distribution, a hybrid approach that replaces sharp uniform boundaries with smooth, continuously differentiable Gaussian tails. This design allows neural networks to learn robust posterior approximations across the entire parameter space by providing training data that extends beyond the primary region of interest, eliminating the discontinuities that plague traditional uniform sampling methods. By validating our method on both synthetic and real cosmological inference problems, we show that the Tailed-Uniform posterior produces probability density functions that closely resemble the reference posterior when compared to conventional uniform sampling.

Kyle Tong SEAS'27, Computer Science

Faculty Mentor(s) or Supervisor(s): Brandon Bellows

Title: Patient out-of-pocket costs for antihypertensive single pill combination products with cost caps

Abstract: Importance: Antihypertensive single-pill combinations (SPCs) simplify hypertension treatment and increase medication adherence. However, high patient out-of-pocket costs remain a barrier to their widespread use. Objective: To describe patient out-of-pocket spending on antihypertensive SPCs in the US and estimate reductions with out-of-pocket cost caps. Design: Cross-sectional study using participants from the Medical Expenditure Panel Survey (MEPS) between 2016-2022.
Patients: MEPS participants with hypertension receiving at least one prescription for an antihypertensive SPC. Main Outcomes and Measures: Annual and per-prescription patient out-of-pocket spending (2024 USD) and estimated reductions with two cost caps: a small cap ($4/30 and $10/90-day supply) and a large cap ($11/30 and $33/90-day supply). Results: An estimated 5.8 million US adults had 26.4 million prescription fills for antihypertensive SPCs, with total annual spending of $260.8 million. The median per-prescription cost was $5.53. A small cost cap could reduce spending for an estimated 3.1 million adults (53.6%), totaling $152.8 million in annual reductions. A large cost cap could reduce spending for 1.1 million (18.3%), totaling $61.2 million annually. The SPCs with the highest per-prescription costs were olmesartan/hydrochlorothiazide, valsartan/amlodipine, and valsartan/hydrochlorothiazide.
Conclusions and Relevance: Despite relatively low out-of-pocket costs, a third to half of US adults using an antihypertensive SPC would experience annual spending reductions under two out-of-pocket cost caps. These reductions could lower financial burdens, potentially increasing medication adherence, improving blood pressure control, and cardiovascular outcomes.

Laura Topolski CC’27, Earth Science

Faculty Mentor(s) or Supervisor(s): Tomochika Tokunaga
Title: The Effects of Coastal Hydrological Processes on the Freshwater-Saltwater Interface

Abstract: Saltwater intrusion affects many coastal aquifers around the world, and often contaminates the quality of fresh groundwater that is extracted and utilized by coastal communities for drinking water, agricultural processes, and other daily necessities. Excessive groundwater pumping and land subsidence can inundate coastal areas, but the fluctuation of tides, precipitation, saltwater intrusion, and storm surges also affect the boundaries of the freshwater-saltwater interface. This study focused on the effects of coastal hydrological processes on the freshwater-saltwater interface near the Nabaki River in eastern Chiba, Japan. Electrode sensors were used to measure the resistivity of the groundwater, and a subsurface vertical resistivity profile of groundwater salinity levels at different depths was created using electrical resistivity tomography (ERT) analysis. Groundwater temperature, pressure, and water level data from shallow and deep boreholes at the field site were recorded and aligned with tidal fluctuations and precipitation measurements. The ERT field data from the Nabaki River site revealed that resistivity levels in the transition zone decreased significantly over a 24-hour observation period, despite the temporary increase in fresh rainwater caused by a typhoon. These results indicated an overall increase in salinity within the transition zone. The salinity levels and boundaries of the interface directly affect the quality and safety of the available freshwater in coastal aquifers, which is an essential resource for coastal communities and ecosystems. Future research will include both longer measurement windows and FeFlow numerical simulations to better understand how different coastal hydrological processes affect the salinity levels within the freshwater-saltwater transition zone.

Vasily Tselioudis CC’26, Linguistics

Faculty Mentor(s) or Supervisor(s): Meredith Landman
Title: Nominative and Accusative Case in Modern Greek: Usage with Embedded Clauses

Abstract: In Modern Greek, nouns change form depending on their grammatical role. The nominative case marks nouns that are the subject of a clause, while the accusative case marks nouns that are the object of a clause. However, this becomes complicated when looking at embedded clauses. In the sentence, “She wants her son to become a businessman,” because Greek allows subjects to be dropped and the noun ‘son’ can be in the nominative or accusative case, it can be understood as either the object of the verb “want” or the subject of the verb “become.” Greek’s free word order allows subjects, objects, and verbs to appear in different positions. Thus, a noun appearing in the nominative case after the verb can be interpreted as the noun being the subject of the verb that it follows. In the example above, this means that when the word “son” is in the nominative case following the verb “to want”, the son can also be interpreted as the subject of the verb “to want.” In speech, verbal emphasis clarifies which noun is the subject of the primary verb. Additionally, attaching a possessive marker to a noun can also indicate the gender of the subject, as the possessive marker is required to feature the gender of the possessor. In the example above, the feminine possessive, “her,” could indicate that the mother of the son described is the subject of the

sentence. This poster presents a psycholinguistic experiment investigating how Greek speakers interpret such cases.

Jacob Urias CC'28, Biochemistry

Faculty Mentor(s) or Supervisor(s): Rodney Infante
Title: TNF-α induced Adipocyte Lipolysis is Independent of G0S2

Abstract: Adipose tissue inflammation is a common feature of several metabolically altered conditions, including obesity, cancer-associated cachexia, and inflammatory bowel disease (IBD). While cachexia is marked by significant fat loss and IBD is characterized by chronic inflammation of the gastrointestinal tract, both conditions show elevated levels of circulating Tumor Necrosis Factor-Alpha (TNF-α) and increased adipocyte lipolysis. Although TNF-α–induced lipolysis has traditionally been linked to transcriptional regulation through G0/G1 switch gene 2 (G0S2), recent findings point to an alternative signaling pathway. Our work focuses on understanding how TNF-α contributes to cachexia and whether it requires other cachexia-related factors to exert its fat-wasting, or "cachectin," effects. To investigate this, we biochemically purified both wild-type and mutant forms of TNF-α. We aim to identify the specific signaling pathways and lipase proteins involved in TNF-α–driven adipocyte lipolysis. In addition, we will evaluate the fat-wasting potential of these recombinant proteins in vivo by injecting them into mouse models. These studies will help clarify which immune signals are critical for driving adipose inflammation in chronic disease.

Bailey Van SEAS'28, Chemical Engineering

Faculty Mentor(s) or Supervisor(s): Joseph Ladines-Lim
Title: Causal Impact of a Blood Culture Austerity Measure at a Large Academic Medical Center: A Quasi-Experimental Study

Abstract: Importance: Blood cultures are essential for diagnosing bloodstream infections and guiding therapy. Guidelines recommend collecting 2–3 sets per patient to maximize sensitivity and minimize contamination. In June 2024, a national shortage of BACTEC bottles forced hospitals to adopt conservation measures, but the impact on patient-centered outcomes remains unclear. Objective: To evaluate the effect of a single-set-per-patient restriction on blood culture utilization, clinical outcomes, and diagnostic stewardship during the 2024 national shortage. Design, Setting, and Participants: Retrospective, quasi-experimental study using interrupted time series analysis at three hospitals within a large academic health system in Philadelphia, Pennsylvania, from June 26, 2023, to June 25, 2025. All patients of any age with ≥1 blood culture collected during emergency department visits, observation stays, or inpatient hospitalizations were included. Exposure: Restriction to one blood culture set per patient per 24 hours during the shortage (June 26–December 23, 2024) compared with unrestricted pre- and post-shortage periods. Main Outcomes and Measures: Blood culture utilization, culture positivity, in-hospital mortality, and 30-day readmission. Results: The restriction significantly reduced the number of cultures collected without affecting positivity rates, in-hospital mortality, or readmission rates. Conclusions and Relevance: Restricting to one blood culture set per patient during the national shortage reduced low-yield testing without compromising key clinical outcomes. These findings support the use of diagnostic stewardship to safely conserve resources during supply disruptions.

Maya Velasco CC'26, Neuroscience

Faculty Mentor(s) or Supervisor(s): Wes Grueber
Title: Investigating the Behavioral Role of External Sensory Neurons in Drosophila Larvae

Abstract: Mechanical sensing enables crucial interactions between organisms and their environment, facilitating survival behaviors including mating, parent-offspring relations, source exploration, and escape response. Drosophila provide an excellent model for understanding the neural circuits underlying these adaptive mechanisms. However, a population of body wall mechanosensory neurons, external sensory neurons (ESNs), remain poorly understood regarding their behavioral implications. Preliminary evidence from our lab has highlighted the targeting of ESNs onto A19b interneurons, which belong to the same hemilineage as GABAergic inhibitory interneurons, suggesting that A19b may share this inhibitory characteristic. Thus, we hypothesize that ESNs inhibit larval rolling behavior through this A19b pathway. To test this hypothesis, we optogenetically activated ESNs alongside noxious heat stimulation of class IV nociceptors, which normally evoke escape rolling behavior through basins. This approach allowed us to assess how ESN activation modifies the typical escape response through standard larval crawling and rolling assays compared to controls lacking the light-sensitive protein. Such experiments also present a similar design to the mammalian gate control theory of pain. Our results demonstrate a statistically significant decrease in rolling behavior during ESN light activation compared ot pre-activation periods. Preliminary results also suggest an increase in crawling speed during light activation. Both results are suggestive of inhibitory effects ESNs may play in larval escape rolling behavior, but remain

incomplete. Future studies should investigate how this decrease affects directional speed and movement patterns across different periods, and provide direct behavioral and molecular confirmation of A19b's specific inhibitory role within this circuitry.

Andrea Vergara SEAS'26, Applied Mathematics

Faculty Mentor(s) or Supervisor(s): Mark E Tuckerman
Title: Providing microscopic insights into the charge transport properties of candidate redox active species for redox flow batteries through atomistic simulations

Abstract: Redox flow batteries are promising for grid-scale energy storage because they can easily scale both power and energy storage capacity. However, current technologies rely on expensive and difficult to source redox active species (for example, vanadium-based). Can we develop new combinations of redox active species + electrolytes that are more cost and energy efficient? Previous work by the Tuckerman group has been focused on studying electrolytes by considering quantum nuclear effects in molecular dynamics simulation. In particular, they have focused on hydrogen bonding networks in structured electrolytes that allow for 'proton hopping' through Grotthuss mechanism. This alternative mode of charge transport allows for electrolytes that circumvent the usual inverse relationship between conductivities and viscosities, improving the efficiencies of redox flow battery systems. This summer research project extends upon previous studies by examining the solvation stability of candidate redox active species, anthraquinone and phenazine, solvated in an electrolyte solution of imidazole and acetic acid. It studies the proton transport properties of candidate electrolytes for potential applications in energy generation and storage. Machine learning potential energy surfaces help accelerate molecular dynamics simulations, allowing for longer timescales in simulations while maintaining accuracy. This builds upon previous research, simulating a complete redox flow battery system more accurately by considering the redox active species solvated in the electrolyte solution.

Elizabeth Wallace CC'28, Environmental Chemistry

Faculty Mentor(s) or Supervisor(s): Ngai Yin Yip
Title: Characterizing Monovalent Cation Hydration Effects on Water Uptake of Ion Exchange Membranes

Abstract: Ion exchange membranes are utilized in a wide range of energy and water treatment applications, serving as an invaluable separation technique to desalinate water and recover crucial components. While the discrimination between ions of differing valency (i.e., monovalent versus divalent) as they enter the ion exchange membrane is well understood, the reasons for discrimination between ions of similar valency remain controversial. This study aims to unravel the reasons behind monovalent ion selectivity by examining three prevalent monovalent cations: lithium, sodium, and potassium. Potassium, due to its low hydration energy, can more readily "shed" some or all of its hydration shell water molecules compared to lithium and sodium, facilitating easier entry into the ion exchange membrane. Our objective is to characterize variations in water uptake by ion exchange membranes and associate these differences with the type and quantity of monovalent ions present. In our procedure, FKS50 cation exchange membranes were immersed in solutions of LiCl, NaCl, and KCl with varying ratios of lithium, sodium, and potassium ranging from 1:1, 1:3, 3:1, 1:9, and 9:1. Water uptake was measured by the difference between the wet and dried membranes. Subsequently, the membranes were soaked in CaCl2 solution to desorb ions, and ion chromatography (IC) was utilized to determine the concentrations of these desorbed ions. This experimentation revealed that the lithium cation brings in more water compared to sodium and potassium cations. These findings offer new insights into the mechanism of monovalent ion selectivity within ion exchange membranes.

Justin Wang CC'26, Applied Mathematics, Biochemistry

Faculty Mentor(s) or Supervisor(s): Chao Lu
Title: The Role of TDRD5 in Post-Transcriptional Regulation of LINE1 in Cancer

Abstract: Transposable elements (TEs) are mobile genetic elements present in nearly all eukaryotic genomes. Taken together, many diverse families of TEs, varying in both sequence and mechanism of mobilization, have contributed to the makeup of approximately half of the human genome. Among these, long interspersed nuclear element 1 (LINE1) stands out as the only active human TE encoding its own transposition machinery, with demonstrated mutagenic and regulatory consequences. LINE1 activity is tightly epigenetically repressed in somatic cells due to its contributions to genomic instability and triggering innate immune responses. In many cancers, global changes in the epigenetic landscape result in aberrant overexpression of LINE1, and post-transcriptional regulatory mechanisms are co-opted to mitigate the detrimental effects of this overexpression. In this project, we investigate a candidate protein, TDRD5, that may play an important role in the adapted post-transcriptional repression of LINE1 overexpression in cancer. First, we evaluated basal levels of TDRD5 and LINE1 expression in the K562 and BICR78 cancer cell lines, as well as an artificially established LINE1-overexpressing system in 293T cells. We then conducted, isolated, and validated CRISPR-Cas9 knockouts of TDRD5 in single-cell derived populations corresponding to each of these cellular contexts. We expect that knockout of TDRD5 in contexts of high LINE1 activity will further increase LINE1 expression and also upregulate markers of the type I interferon response. In future work, we aim to identify protein and RNA binding partners of TDRD5 and clarify the complexity of the LINE1 regulatory landscape, opening new opportunities for therapeutic targeting.

Thomas Wang SEAS’26, Applied Physics

Faculty Mentor(s) or Supervisor(s): Christopher J. Hansen
Title: Coupling ThinCurr and GPEC to Assess the Stability Implications of Induced Currents in Fusion Devices

Abstract: Understanding the interaction between plasma currents and eddy currents driven in device-specific structures is crucial for predicting plasma stability and confinement. We present a new workflow that couples ThinCurr—a thin-wall electromagnetic modeling code—and the Generalized Perturbed Equilibrium Code (GPEC), which can calculate the resonant coupling between external perturbations and toroidal plasmas. Time-dependent field perturbations of vacuum vessel eddy currents and current filaments for coils and plasma are computed on a GPEC-defined control surface. One-dimensional and two-dimensional Fourier analysis is performed on the calculated field, which can be input to GPEC for calculating the plasma response. This integrated computational approach adds field perturbation Fourier analysis capabilities to ThinCurr and offers a streamlined coupling to GPEC, facilitating the study of equilibrium device responses to error fields. The workflow will be exploited to analyze the effects of wall eddy currents and induced currents in closed-circuit Runaway Electron Mitigation Coils (REMC) during plasma current quench and start-up.

Rachel Warner CC’27, Environmental Biology

Faculty Mentor(s) or Supervisor(s): María Uriarte
Title: Hurricane Impacts on Seed Production in a Tropical Rainforest

Abstract: Disturbance events, such as hurricanes, are increasing in frequency and intensity due to climate change. Hurricanes impact forest dynamics by reshaping the canopy structure, altering resource availability, and shifting species composition. Seed production and dispersal are crucial for forest regeneration following a disturbance. However, few studies have evaluated the relationship between hurricane damage and seed production. To assess the spatial patterns of seed production following a hurricane, tree damage and growth following Hurricane Maria were related to seed production observed in the Luquillo Forest Dynamics Plot (LFDP) in Puerto Rico. Tree damage and census data following Hurricane Maria were used to quantify basal area loss and growth surrounding seed phenology baskets at varying distances. Generalized additive models (GAMs) were developed using basal area loss and growth and six years of seed rain data across species. The results indicate that basal area loss and growth were both positively associated with seed rain, and these relationships strengthened over time and at increased distances from the phenology baskets. These findings illustrate community resilience in reproduction following disturbance and highlight concurrent recovery strategies of basal area growth and seed production. As disturbances intensify under climate change, their impacts on seed phenology will shape forest regeneration and species composition.

Marcella Willett CC’28, Environmental Biology

Faculty Mentor(s) or Supervisor(s): Viorel Popescu
Title: Estimating Brown and Black Bear Abundance from Noninvasive Genetic Monitoring

Abstract: Noninvasive genetic monitoring is a powerful tool for conservation and wildlife management and has been growing in popularity as a relatively cost-effective and accurate method of estimating population sizes. Particularly, noninvasive genetic monitoring techniques using scat and hair samples have become one of the primary methods of studying brown bear populations. This study conducts a meta-analysis of noninvasive genetic monitoring studies in brown bear (Ursus arctos) and black bear (Ursus americanus) populations over the past 10 years from across their ranges in North America, Europe, and Asia. Data was extracted from 108 studies (78 for the preliminary analysis) on sampling methods, study area, number of samples analyzed and successfully genotyped to an individual bear, number of individuals identified, and population estimates. According to preliminary results, genotyping success rates tended to be slightly higher for hair than for scat (medians of 62.50% and 52.83% genotyped, respectively), but studies using scat samples tended to identify slightly more unique individuals relative to the number of genotyped samples. This meta-analysis could help to determine the number and type of samples that may be necessary to estimate the size of a population in a certain scale range. Additionally, this study can serve as a baseline of comparison with future studies to evaluate

improvements in the efficacy of genetic methods for population monitoring and to detect potential errors or biologically non-plausible results of brown and black bear monitoring efforts.

Wiann Wilson CC’28, Comparative Literature, Sociology

Faculty Mentor(s) or Supervisor(s): Tara Gonzalves
Title: Writing the National Man: Masculinity, Kinship, and Nation-Building from Colonial to Postcolonial Ghana

Abstract: My research examines how ideas of masculinity in Ghana transformed between the late colonial period and the rise of nationalism, with a focus on the language used in newspapers and political texts. By comparing pre-colonial Ghanaian press materials to speeches and manifestos from the Convention People’s Party (CPP) during the nationalist movement, I explore how masculinity was strategically reshaped to serve emerging political ideologies. I found that the CPP’s secular nationalist discourse drew heavily from colonial-era Christian family values introduced by the Basel Mission. While framed as modern and progressive, these values reinforced a patriarchal nuclear family model that displaced indigenous matrilineal kinship systems. The CPP’s condemnation of polygamy aligned with colonial Christian norms but also disrupted matrilineal structures that supported extended households and distributed caregiving roles. In matrilineal societies, masculinity was relational and collective—shaped through the roles of maternal uncles and elders—whereas the nuclear model centralized authority in the individual father. In this project, I analyze how this shift impacted the transmission of ideas of masculinity within family units, and how the marginalizing of maternal figures within nuclear structures may have served the CPP’s political goals. Ultimately, I argue that colonial and postcolonial institutions redefined masculinity to align with state-building objectives, constructing the ideal “national man” and limiting alternative expressions of male identity rooted in Ghana’s kinship past.

Ray Wu CC’28, Film and Media Studies, Mathematics

Faculty Mentor(s) or Supervisor(s): Adam Stepan
Title: Changing trends in Uzbekistan's education system

Abstract: Travelling to Uzbekistan over the course of summer 2025, the team interviewed and documented the experiences of Uzbeks. The trip covered a wide range of communities, comparing and contrasting the different ideologies and attitudes towards the future. In the wealthy capital city of Tashkent, students and parents flock to the saturated market of private English education, betting their future on the prospects of studying in a university in the Western world. Language tutoring centers decorate every street corner, taking over the remnants of Soviet architecture as English replaces Russian as the language of opportunity. In the historical Silk Road cities of Bukhara and Samarkand, languages of instruction like German and French exist in public schools that feature special programs. The diversity of ethnic groups that exists there keeps people mindful of their past. In the small towns of Navioy and Qarshi, we see student entrepreneurs, themselves unsure of their future, selling courses and hosting Telegram channels of tens of thousands of others who long for an education abroad, in an attempt to generate enough income to leave the town behind. In the far-flung corner of Muynak, the remnants of Soviet bio-chemical weapon testing, along with the drained inland Aral Sea, threaten the health of the next generation. The residents cling to their traditional land and their independent Karakalpak identity. As we conducted interviews about education, we listened to tales personal, perspectives national, and gathered a glimpse of Uzbekistan’s future in the hands of the next generation.

Cooper Xie SEAS’27, Electrical Engineering

Faculty Mentor(s) or Supervisor(s): Xiang Meng
Title: Photonic Circuit Design Automation with AI Agents on Scalable Microring-based Switch Arrays

Abstract: As AI models continue to grow and demand higher-performance hardware, photonic integrated circuits (PICs) offer a promising solution to the bottleneck of electrical interconnects by providing faster training speeds at a lower energy consumption and smaller footprint. Realizing this vision requires close photonic and electrical co-design and, critically, more accessible PIC design workflows. Today, PIC design remains challenging due to specialized physics, foundry-specific rules, and fragmented toolchains. To lower these barriers, we propose using large language models to translate natural language specifications into fabrication-ready PIC design layouts. This work demonstrates the development of a PIC layout through natural language input to GPT-4o, generating a device that achieves the outlined goals. Specifically, it explores the ring resonator-based spatial and wavelength-selective switch (SWSS). After an initial contextualization, GPT-

4o generates the layout of a scalable N-inputs by N-outputs switch across N wavelength channels. The output is provided as a Python file suitable for generating a layout through GDSFactory, a prevalent Python API for larger PIC design. The resulting layout is topologically functional, scalable by configuring parameter N, and includes electric routing that is compatible with conventional flip-chip packaging. This approach enables users with minimal PIC background to create reliable, scalable, and fabrication-ready devices, while also reducing repetitive work for experienced PIC designers.

Heng Yang SEAS'27, Chemical Engineering

Faculty Mentor(s) or Supervisor(s): Stephen X. Skapek, M.D.
Title: A Cis-Regulator of Alternative Splicing in Human MYOD1

Abstract: MYOD1, a key protein involved in muscle differentiation and proliferation, is implicated in diseases such as rhabdomyosarcoma (RMS), characterized by the overgrowth of skeletal muscle cells, and Duchenne Muscular Dystrophy (DMD), characterized by the depletion of muscle satellite cells. Alternative splicing of MYOD1 offers possibilities in controlling gene expression and protein functions. Comparative genomics between mouse and human genomes identified a conserved intronic motif downstream of exon two that contains a consensus binding sequence for SRSF2, a ubiquitous splicing factor, suggesting functional importance. This study will investigate the significance of the binding sequence as the candidate cis-acting regulator of MYOD1 exon two inclusion. We hypothesized that SRSF2 binding at this element promotes the retention of exon 2 in mature mRNA. To investigate, we engineered a MYOD1 minigene retroviral reporter (MDT-GFP), verifying integration via GFP and alternative splicing via tdTomato. We mutated the reporter to delete the SRSF2 binding octamer and confirmed through sequencing. Next, we integrated the MDT-GFP and MDdSRSF2T-GFP reporters into the virus and determined their titer. We then transduced Rh30 and C2C12 cells with reporters and quantified exon 2 "skipping" using live-cell fluorescence microscopy and RT-PCR. Preliminary results demonstrate that knockout of the predicted SRSF2-binding site shifts splicing toward the exon-skipped isoform. These results support the importance of the cis element and suggest SRSF2 facilitates the inclusion of exon 2 in MYOD1. By defining how cis-acting factors regulate alternative splicing, we open therapeutic avenues to manipulate MYOD1 to either halt proliferation in RMS or promote it in DMD.

Roger Yang CC'28, Physics

Faculty Mentor(s) or Supervisor(s): Marija Drndic

Title: Solid state nanopore-informed statistical modeling of single-molecule protein folding

Abstract: Advanced solid-state nanopore measurements at high sampling rates and signal-to-noise ratios (SNRs) generate insights into biomolecular structures with single-molecule resolution. In the case of folding proteins, subtle structural changes can occur rapidly and reversibly, and their detection requires low-noise, ultra-high bandwidth measurements and robust signal analysis methods. This study demonstrates a nanopore-informed technique for statistical modeling of structural reconfiguration dynamics in single proteins using the multi-state folding heme protein cytochrome c. Resistive pulse signals generated by the protein reveal probabilistic transitions among a set of discrete configuration states. Finally, the implications, limitations, and applications of this model are discussed, including simulation of protein behavior at the mitochondrial membrane.

Bambi Yi GS'26, Biology

Faculty Mentor(s) or Supervisor(s): Sarah Hansen
Title: Establishing Reliable Qualitative Coding with Johnstone's Triangle in Chemistry Education Research

Abstract: This study examines the methodological reliability of qualitative coding among different coders when analyzing student reasoning in chemistry education. The research involves interviews in which undergraduate participants were presented with written chemistry problems and asked to provide an answer, rate their confidence, and explain their reasoning. The transcribed responses were segmented into sentence-level units, each treated as an independent coding segment. Each sentence was categorized according to a conceptual framework based on Johnstone's Triangle: macroscopic (observable phenomena in the experiment), submicroscopic (model proposed to explain the observation), and symbolic (symbols that represent the models). Three independent coders used a collaboratively constructed codebook to assign a conceptual level to each sentence without discussion. The primary objective was to assess the consistency and replicability of the coding framework across multiple raters. Coders applied a shared codebook to sentence-level transcript segments, identifying the dominant conceptual level of Johnstone's triangle expressed. Inter-rater reliability(IRR) was assessed using Krippendorff's Alpha to quantify coding consistency and identify patterns of divergence. The study suggests that with a clearly defined codebook and systematic IRR assessment, Johnstone's Triangle can serve as a reliable framework for categorizing student reasoning in chemistry education.

This study contributes to ongoing efforts to the analysis of qualitative interview data within STEM education contexts and education researchers seeking to code interview data with collaborative rigor.

HeeJee Yoon CC'27, Creative Writing

Faculty Mentor(s) or Supervisor(s): Clay Lacefield
Title: A New Transgenic Imaging Strategy for Studying Adult-Born Granule Cells

Abstract: In most regions of our brain, our neurons follow the principle that all you're born with is all you get. In fact, following early development, the brain changes not by generating new cells, but by pruning, cutting back on cells to strengthen synaptic connections. One prominent exception to this clause is a region called the dentate gyrus, known for memory formation. Here, we uniquely find new neurons born later in life, adult-born granule cells (abGCs). This deviation raises questions about the function of these abGCs: what makes this population so special that they continue to be generated later in life? Given that they are part of a critical learning and memory circuit, what role do they play in ensuring that our brains are adaptive? This project focuses on developing a transgenic approach to observe the activity of abGCs in mouse models using two-photon imaging to begin approaching such questions. We use a transgenic mouse line—Ascl1-CreERT2 crossed with TITL2.0-GCaMP8—that allows us to label abGCs born at the time of tamoxifen injection. Using a tet-off system, we administer doxycycline to suppress GCaMP expression until these cells are at least 4 weeks old, giving them time to develop without interfering with their maturation. This is the first reliable GCaMP labeling of large populations of abGC's and will allow us to explore further questions about their activity during development and after maturation.

Ashley Young CC'26, Sustainable Development

Faculty Mentor(s) or Supervisor(s): Jackie Klopp
Title: ustaining Tradition: Indigenous Resistance to Fast Fashion: Lessons for the Slow Fashion Movement

Abstract: The fashion industry is one of the largest contributors to global pollution, generating 92 million tons of textile waste annually, and responsible for 8 to 10 percent of global greenhouse gas emissions. This waste, along with the environmental degradation caused by fast fashion and overconsumption, underscores the need for sustainable alternatives. Slow fashion, a socially conscious movement that aims to shift consumer mindsets about clothing from quantity to quality to restore environmental impact, ensure fair labor practices, and promote the longevity of garments, offers a viable solution. Indigenous communities worldwide long embodied these principles through traditional textile practices. This research questions how the Indigenous community in Cabanaconde, Peru, engages with and responds to influences from the broader fashion industry while preserving their cultural traditions and values. Focusing on a case study of the production and heritage adornment of festival costumes in Cabanaconde, Peru, this study uses expert and semi-structured interviews with local artisans and wearers, as well as participant observation, to explore how these values might offer alternatives to fast fashion and what modern society can learn from them. Additionally, it investigates whether these practices are at risk of being lost and how communities and consumers can contribute to help sustain them.

Ben Yu SEAS'27, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Francois Chesnais
Title: Establishing continuous perfusion in an iPSC-derived liver model

Abstract: Chronic liver failure is one of the leading causes of death globally, yet treatment options remain limited due to organ donor shortages. In vitro models have emerged as a promising alternative to investigate regenerative medicine and drug metabolism, however, current models lack key physiological features of the human liver, especially vascularization. In this study, we aim to develop a perfused human liver tissue model derived from induced pluripotent stem cells (iPSCs) that mimics human liver function and structure. iPSCs were differentiated into hepatocyte (iHep) organoids and endothelial cells, then combined with fibroblasts into hydrogels with various extracellular matrix (ECM) compositions consisting of Matrigel, fibrin, and collagen. These tissues were seeded on static conditions as a control and onto a gravity-driven perfusion platform to mimic physiological blood flow. This model supported hepatocyte viability across different ECM compositions, but vascular network formation remained limited, indicating the need for further optimization to ECM composition, cell density, and media composition.

Jinghe Zhang CC'28, Computer Science, Mathematics

Faculty Mentor(s) or Supervisor(s): George Dragomir
Title: From Headlines to Holdings: Deep Learning for Smarter Portfolio Decisions

Abstract: Recent advances in deep learning have sparked growing interest in its application to stock portfolio optimization. Traditional methods typically

predict returns for individual assets in isolation—ignoring inter-asset dependencies—and then apply mean-variance optimization (MVO) or other methods to optimize the return. However, this disconnection can lead to compounding errors and suboptimal portfolio performance. Our project proposes an end-to-end deep learning framework that directly learns portfolio weights from raw data. The model integrates Long Short-Term Memory (LSTM) networks to capture temporal patterns in stock features and Graph Attention Networks (GAT) to model dynamic inter-stock relationships. It also incorporates sentiment analysis of financial news to reflect market psychology. The training objective of our model is to directly optimize portfolio performance by maximizing the Sharpe ratio of testing period, which balances return against risk. The model used data from nine major stocks across six sectors from the US stock market from January 2021 to May 2025. Our approach significantly outperforms equal-weighted and CAPM-based MVO portfolios in terms of cumulative return and Sharpe ratio. The study explores the effectiveness of the LSTM-GAT model in portfolio allocation and evaluates the added value of sentiment data. Our findings highlight the potential of combining deep learning and natural language processing to enhance portfolio management.

Kai Zhang GS'26, Computer Science

Faculty Mentor(s) or Supervisor(s): Brian Placher
Title: Interior-Point Constraints for Parallel Multi-Shooting DDP

Abstract: This poster presents the integration of primal–dual interior-point (IP) constraint handling into an existing parallel multi-shooting Differential Dynamic Programming (PDDP/MS-DDP) pipeline
on GPUs. Prior work has established stage-parallel DDP and iLQR on modern accelerators; our focus is to endow that pipeline with efficient, general inequality-constraint handling while preserving its stagewise parallel structure and low iteration cost. We adopt the Interior-Point DDP (IPDDP) formulation and embed primal–dual updates inside each multi-shooting stage while retaining the familiar backward–forward DDP loop. In the backward pass, each stage forms a quadratic Bellman subproblem and solves a small Newton system that couples the control and dual variables to produce affine feedback gains (α,β) (and dual updates); an infeasible-IP variant introduces slack variables y≥ 0 with c(x,u) + y= 0 and s⊙ y= μ, while the feasible-IP variant maintains strict c(x,u) <0 and s>0. The forward passapplies u+ = u^+ γ(α+ β(x^+− x)), propagates dynamics, and evaluates constraints. A CPU-managed line search preserves feasibility (feasible-IP) or positivity of (s,y) (infeasible-IP) and reduces the barrier parameter μwhen KKT-like residuals are small. Early iterations are stabilized by lightweight Tikhonov regularization of Quu; along the central path, curvature becomes positive and the method exhibits local quadratic convergence under standard assumptions. Crucially, all added linear algebra remains per-stage and batched, so the GPU parallelism of PDDP is retained. We provide an initial characterization on a 7-DoF KUKA LBR IIWA-14 figure-eight tracking task. Using our existing parallel iLQR/MS-DDP implementation as the baseline and a contemporary optimal-control library for comparison, we profile per-iteration latency and kernel-level time distribution. The IP layer enforces input and state inequality constraints with modest overhead relative to the unconstrained baseline, and avoids the step-scaling sensitivity commonly observed with pure log-barrier approaches after barrier reductions. Preliminary measurements indicate favorable scaling with horizon length and improved GPU occupancy versus unconstrained MS-iLQR under matched hardware settings. Scope and significance. The resulting constraint-aware PDDP is a practical building block for high-rate model-based control in autonomous manipulation and locomotion, where constraint satisfaction and computational throughput are equally critical. Ongoing work replaces the iLQR approximation with exact second-order information, explores adaptive barrier scheduling and predictor–corrector steps, and extends the formulation to hybrid robotic systems and manifold state spaces.

Melanie Zhang GS'26, Religion

Faculty Mentor(s) or Supervisor(s): Dominique Townsend
Title: Tibetan Buddhist Approaches to Social Action: the 1750 Lhasa Uprising

Abstract: This summer project investigates how Changkya Rolpai Dorje (1717-1786), the Buddhist Geluk lama who served as imperial preceptor to the Qianlong emperor, negotiated authority after the 1750 Lhasa uprising, when the Tibetan regent was assassinated and anti-Qing riots shook the city. Drawing on legal decrees, edicts, and monastic constitutions, this project examines how legal rules and patronage shaped sectarian politics in Tibet and how Buddhist ethics informed strategies of governance. It adopts the concept of karmic historiography, which interprets law not only as rules but as narratives of cause and effect linking moral choices to social outcomes. The analysis highlights three case studies, including an edict of 1748 granting monks tax exemptions in exchange for ritual service and the 1751 Qing reforms, in which Rolpai Dorje persuaded Qianlong to restore authority to the Tibetan community. Each illustrates how Buddhist approaches to social action -- discipline, compassion, and skillful means -- were translated into

legal and political practice. Finally, the project also laid a foundation for my incoming fall project regarding the nineteenth-century Ri-me (pluralism) movement, showing how Buddhist pluralist responses emerged from cycles of crisis and reform.

Ray Zhang CC'27, Biology

Faculty Mentor(s) or Supervisor(s): Martin Chalfie
Title: Identifying Novel Genes Involved in C. elegans Touch Sensitivity

Abstract: C. elegans is a small nematode whose biology makes it possible to observe how cellular-level changes lead to system-wide effects. This advantage, along with C. elegans' well-characterized touch reflex circuit, make it ideal for studying mechanosensation. To investigate the factors that affect the touch reflex circuit, Terese Lawry, a graduate student in the lab screened the Million Mutation Project (MMP) library, a fully sequenced collection of 2,006 mutagenized strains, for strains with defects in touch sensitivity. Of the 105 touch-defective strains, 65 strains had mutations in genes known to be involved in touch sensation. This project aimed to characterize the phenotypes of the 40 remaining strains and determine their causative mutations. Of the 27 strains tested so far, 16 showed strong touch insensitivity, while the remaining 11 had weak phenotypes and were not pursued. Three of the strongly touch insensitive strains also exhibited twitching, characterized by rapid muscle contractions unrelated to touch, and were excluded. Another three strains displayed rapid habitation characterized by loss of responsiveness after one to three gentle touches, suggesting defects in downstream signaling rather than in the touch receptor neurons themselves. Among the three habituating strains, one inherited the phenotype through an X-linked recessive mutation, while the other two exhibited autosomal recessive mutations leading to the habituating phenotype. Further testing revealed that both autosomal recessive strains share mutations in the same gene, rexd-1. Future experiments will identify the causal mutation by sequencing and validate its effect. This work will further the understanding of the molecular basis of habituation and touch sensation in C. elegans and could uncover conserved mechanisms in other animals, including humans.

Ruqi Zhang CC'27, Biology

Faculty Mentor(s) or Supervisor(s): Sara Zaccara
Title: Impact of selective residue substitution on the YTHDF2 cytosolic m6A reader function and its implications in Acute Myeloid Leukemia (AML)

Abstract: YTHDF are a family of cytosolic reader proteins of the mRNA modification N6-methyladenosine (m6A). Though previously believed to hold distinct functions, the three members of the YTHDF protein family (YTHDF1, YTHDF2, YTHDF3) have been recently shown to redundantly promote degradation of their target mRNA, and exhibit compensatory responses to depletions of each other depending on cell type and levels of expression. Acute Myeloid Leukemia is characterized by the abnormal proliferation of immature myeloblasts, which has been shown to be inhibited by YTHDF protein depletion through accelerated cell death or differentiation. However, the specific mechanisms of this association remain unknown. This project stands on my lab's previous findings of YTHDF2 sufficiency for cell viability in HeLa cells under YTHDF1/3 knockout conditions, and aims to further explore and verify the findings of a previous CRISPR screening on five crucial residues identified to have yielded the greatest change in cell proliferation scores. We hypothesize the difference in cell proliferation to be caused by phosphorylation-related cellular localization of the YTHDF protein, and therefore expect to observe decreased cell survival in three of the specified sites, and aim to gather further data on the two other sites that have previously increased cell proliferation. This study employs CRISPR guided base editing administered through lentiviral transduction, and the established cell lines were then tested on a cell proliferation assay and their genome extracted for sequencing to verify mutation. However, there has not yet been sufficient data to conclusively support or deny our hypothesis.

Emily Zhao CC'28, Biology

Faculty Mentor(s) or Supervisor(s): Karen Dunbar
Title: Delineating the role of Wnt signaling in CAF-mediated tumor cell proliferation

Abstract: Esophageal cancers, comprised predominately of esophageal adenocarcinoma (EAC) and esophageal squamous cell carcinoma (ESCC), are the 6th leading cause of cancer deaths around the world. Cancer-associated fibroblasts (CAFs) support esophageal cancer progression through the secretion of cytokines and growth factors, metabolite exchange, and extracellular matrix remodeling. CAFs are a heterogenous population comprised of two main phenotypes; myofibroblastic CAFs (myCAFs) and inflammatory CAFs (iCAFs), both of which have significant roles in tumor progression. EAC displays an increase in canonical Wnt signaling, a pathway that controls cell proliferation and has been shown to induce myCAF phenotypes in colorectal cancer. The goal of this project is to elucidate how canonical Wnt signaling modulates CAF function, and therefore EAC

progression. Modulation of Wnt signaling (activation or inhibition) altered expression of CAF phenotype markers. Co-culture of CAFs and organoids resulted in increased number of organoids and increased organoid proliferation compared to mono-cultures, suggesting CAFs induce tumor cell proliferation. Concurrently, I optimized a cyclic IF protocol to stain for markers of proliferation, Wnt signaling, and cell-types. This sequential staining facilitates the quantification of proliferation and Wnt signaling activity in both tumor cells and CAFs in orthotopic mouse EAC tumors. Future directions include using this cyclic IF protocol on fixed organoid-CAF co-cultures, quantifying how EAC tumor-fibroblast interactions affect Wnt signaling in both populations, using different Wnt inhibitors with organoid-CAF co-cultures to further elucidate how Wnt modulates CAF phenotypes, and increasing biological replicates across both ESCC and EAC cell lines in qRT-PCR and organoid and fibroblast co-cultures.

Jason Zhao CC’28, Computer Science

Faculty Mentor(s) or Supervisor(s): Paul Glasserman
Title: Investigating Total Positivity Order of Two Violations in Applied Stochastic Structures

Abstract: Conceptually, a function is totally positive order of two (TP2) if bigger values of one input naturally go with bigger values of the other input, and smaller values go with smaller ones. When looking at functions with inherent randomness in the real-world, TP2 violations can present very interesting scenarios. An example of such a function is option contracts (financial contracts giving buyers the right, but not the obligation, to buy or sell an underlying asset at a fixed price on or before some date) in the financial markets. Two of the option contract types of interest are European and American-style contracts, with European options being exercisable only on the expiration date and American options being exercisable at any time up to and including the expiration date. Generally, European-style call and put option contract prices can be modeled using the Black-Scholes equation, and prices are usually TP2. Prices are also usually TP2 for American-style (contracts) call and put option contract prices, which can be modeled using binomial and trinomial lattice methods. Because these methods are theoretical, they may sometimes fail to predict TP2 violations for contracts. Previously, conditions under which European call and put options violate TP2 were found by Glasserman et al., and this project aimed to understand if similar results could be found when looking at American call and put options. An analysis of historical SPY and SPX option parameters and prices was conducted to compare the characteristics of TP2 violations for American and European option contracts, respectively. After this analysis, it was found that, for the given months analyzed, American options exhibited TP2 violations less frequently and with lower magnitudes. For future research, it will be necessary to expand this analysis to include greater time frames and other stock indices.

Ruimian Zheng CC’27, Mathematics, Physics

Faculty Mentor(s) or Supervisor(s): Elias Most
Title: Realistic Baryon-Ejection from the Recoil of Magnetar Giant Flares

Abstract: Magnetars are neutron stars (NS) that have extremely strong magnetic fields, typically with strength G. These magnetars power a range of transient outbursts, with Giant Flares (GFs) being the most energetic ones. Among a few observations we have of GFs, the most notable of is SGR 1806-20, giving us the phases of GFs: an initial second-long gamma-ray spike, a minute-long pulsating x-ray tail, an hour-long MeV component, and a radio afterglow that appears weeks and months later. Recent models by Cehula et al. predict baryon-ejection from the “recoil force” of the GFs to explain the GF radio rebrightening and identify the potential for r-process. We performed 2D GRMHD simulations using AthenaK to localize the shock and observe the ablation of the crust at various initial conditions. Due to the nature of a 2D simulation, we neglect the rotation of the magnetar, given that magnetars typically rotate slowly compared to other neutron stars. Under the preliminary set-up, we will follow the 1D model to assume that the magnetic field has been mostly dissipated during the giant flare outflow. By varying the equation of state, we probe different regimes of the neutron star crust. We systematically quantify the mass ejection, and find that the total ejected mass is approximately $10^{-8.5} - 10^{-5}$ solar masses. The ejecta mass varies exponentially with parameters including the initial hit velocity, the concentration, and the shock depth. The ejecta mass and the ejecta velocity in the 2D GRMHD simulation are sufficient as required by the radio afterglow model.

Kate Zhu SEAS’28, Biomedical Engineering

Faculty Mentor(s) or Supervisor(s): Gordana Vunjak-Novakovic
Title: COX-2 Inhibition Reduces Fibrosis through IL-11 in Fibroblast BAG3 KO Tissues

Abstract: Heart disease is increasingly prevalent and is the leading cause of death globally. One form of heart disease, dilated cardiomyopathy (DCM), is characterized by ventricular dilation, poor contractility and increased

myocardial fibrosis. Mutations in bcl2-associated athanogene 3 (BAG3) are known contributors of DCM. Although previous research focuses on BAG3 knockout in cardiomyocytes, the main muscle cells of the heart, our lab sought to study the effects in cardiac fibroblasts. Cardiac fibroblasts are the main extracellular secreting cells, which lead to cardiac fibrosis, a key marker of DCM. We used high-throughput screening and machine learning to isolate DuP 697 as the top drug candidate that can recover the diseased DCM phenotype in cardiac fibroblasts. We applied DuP 697 on engineered heart tissues (EHTs) and found improved active force using our lab's milliPillar bioreactors and possible downregulation of collagen in cardiac fibroblast-specific knockout of BAG3. Mechanistically, DuP 697 is a COX-2 inhibitor and we sought to investigate how it can ameliorate force production. To do so, we performed RT-qPCR on the BAG3 knock-out fibroblasts. DuP 697 reduced TIMP1 and LOXL3, ECM remodeling genes, and downregulated IL-11 and downstream signaling pathways, however, did not directly impact ECM secretion. When extending the study to other COX-2 inhibitors, we observed active force recovery in EHTs, but no difference in collagen deposition. Together, these results suggest COX-2 inhibition, leading to IL-11 inhibition, as a novel therapeutic target for ameliorating force production in BAG3-mediated DCM.

Miriam Zhu SEAS'28, Applied Mathematics

Faculty Mentor(s) or Supervisor(s): Chunhua Weng
Title: Benchmarking OpenAI's ChatGPT-4o for Clinical Case Entity Extraction

Abstract: Entity extraction is widely performed on Electronic Health Records, clinical notes, and medical literature to advance biomedical research and create a large database for diagnostic tools. However, manual entity extraction by clinicians is extremely time consuming and there remains no gold standard among Large Language Model (LLM) entity extraction, especially as it pertains to entity boundaries. In this study, we evaluate OpenAI's ChatGPT-4o's ability to perform entity extraction on clinical cases from the New England Journal of Medicine by comparing its output against the clinician gold standard, as established by six multidisciplinary clinicians from Columbia University Irving Medical Center. Applying statistical methods to analyze over 3000 total extracted entities, we find that ChatGPT often extracts more and longer entities than clinicians from a single clinical case. ChatGPT entities are on average 1.88 words longer than clinicians' and often contain a shorter clinician concept within it. ChatGPT entities often include qualitative, quantitative, temporal, local, and intensity descriptors, which contributes to a lower chance of matching its entities to standardized dictionaries like SNOMED. Furthermore, clinicians took between 30 minutes to two hours to extract entities from one case, whereas ChatGPT took seconds. From these findings we propose a new method for entity extraction that combines the time efficiency of ChatGPT and the accuracy and precision of clinicians to advance scalable, accurate entity extraction for clinical text.

Sophie Zhu SEAS'28, Chemical Engineering

Faculty Mentor(s) or Supervisor(s): Jingguang Chen
Title: Nickel Foam as an Effective OER Catalyst for CO2RR and HER

Abstract: Increasing anthropogenic carbon dioxide (CO_2) emissions have led to the acceleration of climate change. To address this, recent studies convert CO_2 into value-added chemicals, but most end up as single-use plastics and fuels with short-term carbon storage potential. To achieve net-negative emissions, a tandem electrochemical-thermochemical reactor system was developed to convert CO_2 and water into renewable hydrogen gas and solid carbon nanofibers, which have long-term storage potential. The upstream electrochemical reactor converts CO_2 and water into carbon monoxide and hydrogen (syngas), which the downstream thermochemical reactor utilizes to produce carbon nanofibers. Iridium oxide is commonly used as the oxygen evolution reaction (OER) catalyst, but platinum group metals (PGM) like iridium are expensive, limiting their industrial applicability. This project focuses on non-PGM OER catalysts, with nickel foam recently identified as a promising option for water electrolysis. To study nickel foam in CO_2 reduction schemes, H-cell experiments were conducted to compare the catalyst activity of nickel foam (pristine and modified) against iridium oxide in a potassium bicarbonate electrolyte. Electrochemical impedance spectroscopy, linear sweep voltammetry, and other electroanalytical techniques were used to measure important catalyst parameters like electrochemically active surface area (ECSA). These results indicate that iron chloride modified nickel foam is competitive against commercial iridium oxide, especially when their activities are normalized by cost. After identifying a promising non-PGM OER catalyst, future work entails synthesizing and characterizing a non-PGM CO_2 reduction reaction catalyst, with hopes of developing a cost-effective solution for converting CO_2 and water into syngas for downstream tandem catalysis.