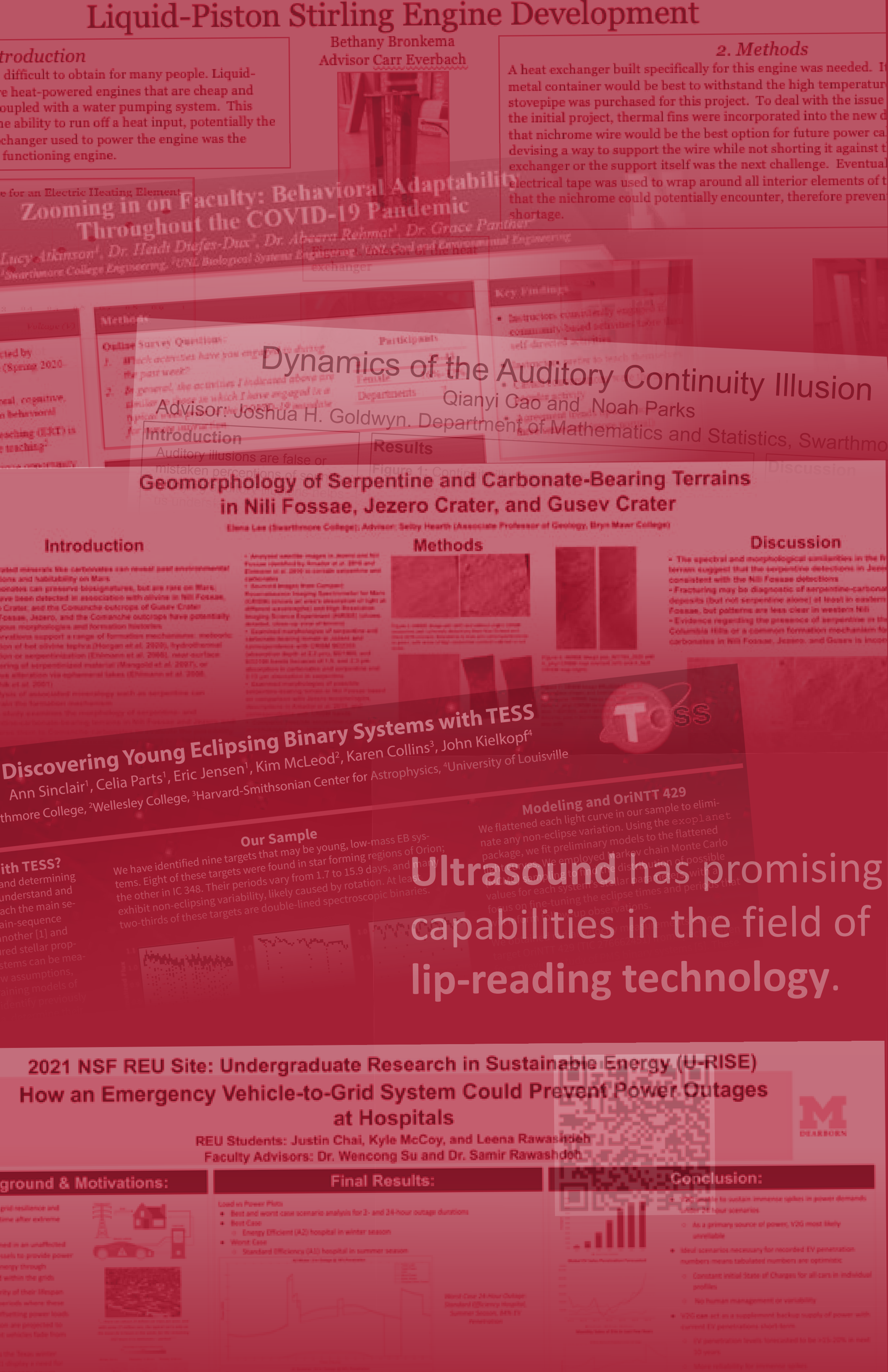
SIGMA XI
THE SCIENTIFIC RESEARCH HONOR SOCIETY

SWARTHMORE

Student Research Poster Session

September 30, 2021 ▪ 3 PM - 5 PM + October 1, 2021 ▪ 11:30 AM - 2 PM



Liquid-Piston Stirling Engine Development
Bethany Bronkema
Advisor Carr Everbach
2. Methods
Zooming in on Faculty: Behavioral Adaptability Throughout the COVID-19 Pandemic
Dynamics of the Auditory Continuity Illusion
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Ultrasound has promising capabilities in the field of lip-reading technology.
2021 NSF REU Site: Undergraduate Research in Sustainable Energy (U-RISE)
How an Emergency Vehicle-to-Grid System Could Prevent Power Outages at Hospitals
REU Students: Justin Chai, Kyle McCoy, and Leena Rawashdeh
Faculty Advisors: Dr. Wencong Su and Dr. Samir Rawashdeh
Final Results:
Conclusion:

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SIGMA XI
THE SCIENTIFIC RESEARCH HONOR SOCIETY

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4	Suleyman Amjad		Engineering	Zeeman Effect in HeNe Lasers
5	Kaja Arusha	Krystle Boadi, Sabrina Ellah, Daniela Kim	Biology	Cross-fostering and its effects on postnatal growth and endocrine stress response in the social rodent Octodon degus
6	Lucy Atkinson	Dr. Heidi Diefes-Dux, Dr. Abeera Rehmat, Dr. Grace Panther (University of Nebraska-Lincoln)	Engineering	Zooming in on Faculty: Behavioral Adaptability Throughout the COVID-19 Pandemic
7	Deven Ayambem	Dr. Vikas Bhandawat, Liangyu Tao	Engineering	Investigation of Naturalism in Optogenetically Activated Behavior in Drosophila
8	Yimeng Bao	Brad Davidson (corresponding author)	Biology	Cardiomyocyte renewal and injury-dependent proliferation in adult Ciona robusta (Ciona intestinalis type A)
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19	Zitong Chen	Kelly Finke, Jeffrey Gauthier, Tyler Boyd-Meredith, David Tank	Biology	Long-term cell tracking using volumetric registration to compensate for brain deformation
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21	Kenny Chen	Kristen Lokken-Toyli, Jeffrey N. Weiser, MD	Biology	Infant host susceptibility to invasive pneumococcal infection
22	Shu Yi Chen	Johanna Lee, Anusha Bhatia	Biology	Applying a Computational Pipeline for the Analysis of Differential HSATII Expression in Cancer Cell Lines
23	Yi Fei Cheng	Yukang Yan, Xin Yi, Yuanchun Shi, David Lindlbauer	Computer Science	SemanticAdapt: Optimization-based Adaptation of Mixed Reality Layouts Leveraging Virtual-Physical Semantic Connections
24	Yi Fei Cheng	Hang Yin, Yukang Yan, Jan Gugenheimer, David Lindlbauer	Computer Science	Towards Understanding Diminished Reality
25	Lonnie Chien	E. Carr Everbach, John M. Cormack, Mark F. Hamilton	Engineering	Determination of nonlinearity parameter B/A of liquids by comparison with solutions of the three-dimensional Westervelt equation
26	Jino Chough	Benjamin Zinszer	Psychology	Artificial Second Language Acquisition from Stable and Unstable Transitions
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29	Thembalami Dube	Safia Bashir, Professor Dawn Carone	BioChemistry	UbH2A Recruitment to HSATII DNA on 1q12 following DNA Demethylation
30	Sabrina Ellah	Ellah, S.S., Arusha, K.S., Boadi, K.D., Kim, D. and Bauer, C.M.	Biology	Does being fostered with siblings prevent play behavior declines in Octodon degus?

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33	Vivian Guo	Karen Chan (advisor)	Biology	Dietary Preferences of Sea Urchins
34	Scout Hayashi	Sophie Engels, Chayanne Petit	BioChemistry	Biophysical Characterization of Influenza A Matrix Proteins 1 and 2
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36	Eva Karolczak	Kelly Finke ('21), Gabriel Straus ('23)	Biology	Hippocampal maps might not be one-size-fits-all
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64	Caleb Scott-Joseph	Catherine Espilliat, Thanawuth Thanathibodee	Astronomy	Using Brackett Gamma to model accretion around T-Tauri Stars
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68	Rachel Sinex	Here is the list of authors: Rachel H. Sinex, Samantha D. Sorid, Evelyn Behar, & Jedidiah Siev Swarthmore College, The College of William and Mary, City University of New York – Hunter College	Psychology	Anxiety Sensitivity and Disgust Sensitivity Predict Blood-Injection-Injury Phobia Symptoms in Individuals with Dental Anxiety
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70	Camryn Slosky	Tiffany Phu, Marisa Stahl, Edwin Liu, Mary Shull, Monique Germone	Psychology	Quality of Life in Mass Screening-Identified Pediatric Celiac Disease
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72	Colby Stoddard	Tristan Smith	Physics	Searching for a Gravitational Wave Background
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85	Zhichun Joy Zhang	Esther Banaian, University of Minnesota - Twin Cities; Amy Tao, Wellesley College	Math/Stats	Friezes from Dissections over $\Z[\sqrt{2}]$ and $\Z[\sqrt{3}]$
86	Catherine Zhao	Mike Voyt, Chad Niederhuth, Robert VanBuren	Biology	Comparative Genomics of Stress Responses in Grasses
87	Krystle Boadi	Boadi, K.D., Arusha, K.S., Ellah, S.S., Kim, D., Bauer, C.M.	Chemistry	Influence of fostering environment on the parental care of a social rodent species
88	Selena She	Wendy Wen , Selena She, Gabrielle Ma, Professor Benjamin Zinszer	Psychology	Modeling Bilingual Semantics Using Word-Embedding Models and Object Naming Tests:
89	Brinton Vandegrift	Vandegrift, BH, CHAN, KYK	Biology	Effect of ocean acidification on predator avoidance of larval sand dollars

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A Bijection Between Parking Functions and the Tower of Hanoi

Yasmin Aguillon, Dr. Pamela E. Harris & Casandra Monroe

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The displacement of a parking function measures the total difference between where cars want to park and where they ultimately park. The set of parking functions of length n with displacement one was found to be equinumerous to the set of ideal states in the famous combinatorial puzzle, the Tower of Hanoi with $n+1$ disks and $n+1$ pegs. In our research, we created two functions that illustrate an explicit bijection between the two sets.

Examining the Zeeman Effect in Helium Neon Lasers

Suleyman Amjad

In the summer of 2020, I conducted a remote research project relating to Engineering Optics with Professor Lynne Molter. As this research was remote, Swarthmore sent me lab equipment to perform experiments at home. Specifically, my research focused on observing the Zeeman effect of Helium Neon lasers in axial magnetic fields. The Zeeman effect occurs because of the effect of a magnetic field on ½ spin nuclei. Since, the laser is randomly polarized these nuclei become oriented in accordance with the field's direction (either parallel or antiparallel). This phenomenon can be observed in Helium Neon lasers by measuring the beat frequency (difference between the highest and lowest frequencies) of the beam.

Firstly, I constructed a makeshift optics table by repurposing a ping pong table and cutting wooden planks of different widths to create leveling platforms. I created the setup for this experiment by situating a Helium Neon HP-5501 laser onto a platform and properly connecting it to a power source and adjusting a polarizing lens arbitrarily onto the front of the laser tube. The beam was then measured by a photodetector and oscilloscope. Finally, the laser tube was surrounded in an axial magnetic field, via a ring of bar magnets.

After the apparatus was constructed, I was able to successfully observe the beam's beat frequency on the oscilloscope and determine that the Zeeman effect was occurring. Finally, I experimented with different strengths and orientations of magnetic fields and how they effected the extent of the Zeeman effect on the laser.

Cross-fostering and its effects on postnatal growth and endocrine stress response in the social rodent *Octodon degus*

Kim, D, Arusha, K.S., Ellah, S.S., Boadi, K.D., Bauer, C.M.

This study examined the effects of fostering on the postnatal development of the social rodent species, *Octodon degus*. Specifically, we investigated the hypothesis that being fostered with siblings mitigates the negative effects on growth and stress response. Degu litters were in the single cross-foster, complete cross-foster, or control treatment group. Single cross-fostered pups were swapped with another pup and grew up with unfamiliar

parents and siblings. Completely cross-fostered pups had their entire litters swapped and grew up with unfamiliar parents but birth siblings. Control pups stayed with both their birth parents and siblings. We measured weight and stress hormone levels (CORT) from birth to 4 weeks of age. We predicted that control pups would gain the most weight, followed by cross-fostered pups and then single cross-fostered pups. We also predicted that the cross-fostered pups would have unhealthier stress profiles than control pups, and single cross-fostered pups would have unhealthier stress profiles than complete cross-fostered pups. Degus, similar to humans, are a species in which both parents care for young, therefore our data could have implications for the effects of parental and sibling separation on human postnatal development.

Behavioral Adaptability of Engineering Faculty Engaging in Emergency Remote Teaching During the COVID-19 Pandemic

Lucy Atkinson, Dr. Heidi Diefes-Dux, Dr. Abeera Rehmat, Dr. Grace Panther

University of Nebraska-Lincoln, Swarthmore College

The crisis-induced changes in instruction during the COVID-19 pandemic present a unique opportunity to study faculty adaptability, a significant contributor to future adoption of best-practice teaching techniques. A focus on the experiences of engineering instructors during emergency remote teaching reveals important resources and supports necessary for developing faculty adaptability that can lead to the use of best practices in teaching. The purpose of this research is to understand the self-reported activities of engineering instructors throughout the COVID-19 pandemic, the normality of instructors' engagement in these activities, and how these two factors changed over the course of three semesters. The research question addressed in this study is: *In what ways do instructors' activities change over the course of teaching during COVID?* Throughout the three semesters affected by COVID-19, teaching-focused engineering instructors voluntarily completed weekly or biweekly online surveys about their engagement in teaching-related activities and the normality of that engagement. While weekly and semester participation varied by professor, data analysis consisted of descriptive statistics to obtain general trends in activity engagement for each semester and across all three semesters. By the end of the third semester, 85% of participants indicated normality of their teaching methods, suggesting that faculty successfully adapted to pandemic circumstances by engaging primarily in casual conversations with colleagues and self- teaching. These trends indicate that developing a supportive faculty community as well as providing space, time, and resources for faculty self-teaching could encourage future faculty adaptability and adaptation.

Investigation of Naturalism in Optogenetically Activated Behavior in Drosophila

Deven Ayambem, Bhandawat Lab

Drexel University, School of Biomedical Engineering, Science and Health Systems

The ability to adapt to appropriately respond one's environment is important for the survival

of animals. The Drosophila aggression system is a great model system to study how sensory information is processed to generate appropriate behavioral responses due to its relative simplicity and the availability of genetic tools. In the Bhandawat lab, we have found that optogenetic activation (activating neurons with light) of a population of just 35 neurons in sensory processing regions caused flies to perform aggressive actions even in the absence of a target of aggression. Since aggression in nature involves a target, it is unknown whether the activation of these neurons is a part of the aggression neural circuit during normal aggression. Here, I investigated whether the induced aggression is naturalistic by performing behavioral experiments between pairs of flies in which one fly is under optogenetic control. Using deep learning and a 3D triangulation algorithm, we were able to develop a framework to study the interactions between these pairs of flies. Preliminary analysis of the results showed that optogenetic activation of the neurons caused a mix of both naturalistic and non-naturalistic behavior in the presence of another fly. These results provide a framework through which we can study the neural circuitry behind behaviors such as aggression.

Cardiomyocyte renewal and injury-dependent proliferation in adult *Ciona robusta* (*Ciona intestinalis* type A)

Jasmine Yimeng Bao and Brad Davidson

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The lack of regenerative ability in the human heart makes it unable to recover from heart attacks. Reprogramming cells for regeneration, therefore, has gained great research interest for its therapeutic applications. We propose *Ciona robusta* (*Ciona intestinalis* type A) as a simple model for chordate heart growth and regeneration. The basal chordate *Ciona* robusta is a close evolutionary relative to vertebrates with not only homologous cardiac genes but also a low cell number. *Ciona*, moreover, exhibits high regenerative capacity in various organs including the heart. *Ciona* cardiac formation and development during embryonic and larval stages are relatively well-characterized. Here we show how, in adult *Ciona*, cell division and proliferation contribute to growth of the heart and how patterns in cell division respond to injury. Proliferating cells are visualized via the Click-iT EdU cell proliferation assay in adult hearts in vitro and quantified via confocal imaging and cell counting using image analysis software (Fiji). Our results suggest that, during normal heart growth, distal regions of the adult *Ciona* heart exhibit higher cardiac muscle cell proliferation compared to medial and proximal regions. When injured, the adult heart muscle responds to injury with increased cell proliferation, particularly in the proximal region. A linear population of cells, termed the undifferentiated line in previous literature, exhibits increased proliferation in regions adjacent to the site of injury. Follow-up studies investigating signaling pathways that drive *Ciona* heart cell renewal and regeneration are essential for gaining a more sophisticated understanding of the cellular and molecular mechanisms of these processes in chordates.

Influence of fostering environment on the parental

care of a social rodent species

Boadi, K.D., Arusha, K.S., Ellah, S.S., Kim, D., Bauer, C.M.

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This study aimed to identify the impact fostering has on the development of a social rodent species (*Octodon degus*), specifically whether parents provide more care to their biological offspring versus their foster offspring. Degus were assigned one of three treatments: single

cross-foster, complete cross-foster, and control. The single cross-foster treatment consisted of switching one pup from one cage with one pup from a different cage, thus housing each pup with new parents and littermates. In complete cross-foster groups, all siblings were swapped and placed with new parents. In the control group, no cross-fostering took place and pups therefore remained with their biological parents and siblings. We measured parental care by analyzing rates of licking/grooming, parental presence on the nest, and pup carries. We also assessed parental anxiety behaviors (rearing up on the cage side). Parental behavior videos were analyzed every other day beginning on the day after fostering (PND 9) until PND 21. We predicted that in both the control and complete cross foster treatment groups, littermates would receive similar amounts of care. However, we predicted that within the single cross-fostering treatment groups, biological offspring would receive more parental licking/grooming than foster offspring.

Liquid-Piston Stirling Engine Development

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Traditionally, Stirling engines are heat-powered machines with displacer pistons and a confined working fluid that fluctuates in pressure throughout the engine's operation. They also contain a regenerator, which is a place in the engine where some of the working fluid's heat can be stored to be released back into the process on the next cycle, greatly increasing the efficiency of the engine. Liquid-piston Stirling engines (or fluidynes) are Stirling engines whose displacer piston is a liquid, usually water, and the working fluid is air. These engines can be directly coupled with a water pumping system using non-return valves, creating a water pumping system with the ability to run off a heat input which could potentially be the sun.

The goal of this summer research project was to create a functioning fluidyne engine, collect data pertaining to its operation, and then work to optimize its efficiency. This project began as an E90 design in 2006, and so the basic parameters of the engine were already determined, and a large portion of the engine was already constructed. However, after reviewing the previous report, it was determined that the heat exchanger used to power the engine needed to be completely redesigned, which then became the main goal for the development of a functioning engine.

Following the design and initial testing of the heat exchanger , the full engine could be

put together. This fluidyne consists of a large U-shaped section of PVC which contains the water (displacer piston) and is sealed at the top with a section that contains the heat exchanger and the regenerator. The initial regenerator was in good enough condition to be reused, and consists of a 4-in diameter section of PVC with layers of wire mesh and pebbles. Finally, an output tube 23-ft in length was constructed to enable the engine to operate with minimal flow losses.

The initial test run of the engine failed due to obvious air leaks around the heat exchanger, which were then sealed before the next test. The second test resulted in full operation of the engine for a very short time, at which point a PVC fitting melted to a point where significant air leaks occurred again. After this problem was identified and corrected, the final test of the engine resulted in correct operation for a period of 4 hours, at which point the test was concluded and considered successful.

Terrestrial Soundscapes in HKIS and Tai Tam Country Park

Maia Chandler, Paul Hodgson

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Human activity creates anthropogenic noise which can alter the environment's acoustics and impact the surrounding habitats. It can mask acoustic signals animals rely on to communicate, to detect predators and/or prey and to navigate their environment. This can lead to behavioural changes in organisms and impact interspecific interactions, resulting in a change of an ecosystem's species richness and composition. Soundscapes can reveal changes in an environment that images cannot discern. Soundscapes are used to analyse biological, geological and anthropogenic relationships in a given acoustic environment. Though soundscapes have previously been used to investigate marine environments in Hong Kong, they are not commonly used in terrestrial studies.

Hong Kong International School (HKIS) is currently undergoing renovation. Construction greatly impacts the environment surrounding it, destroying habitat and creating noise that hinders the local fauna's ability to communicate and reproduce.

This research used soundscapes to examine how the renovation and presence of HKIS and its community impact the surrounding environment of Tai Tam Country Park. Terrestrial acoustic recordings were conducted using passive acoustic monitoring (PAM) at 5 sites in Tai Tam Country Park and around HKIS between June 2020 and July 2020. Site-specific analyses were performed on the locations and biotic and abiotic noises were separated using a Fast Fourier Transformation (FFT), which aims to facilitate the visualisation, source separation, and event identification of long-duration field recordings. In addition, people counters were used to compare biodiversity areas around HKIS and Tai Tam Country Park.

The paper identifies differences in fauna populations between the HKIS community and Tai Tam country park. The results showed that HKIS's presence and renovations have had a clear impact on the surrounding natural environment. In areas with higher levels of human activity, the animals are less active.

In order to mitigate the impact HKIS has on the surrounding environment, several measures should be put in place to restore the ecosystem, such as compensating for the damage done by HKIS, its community and its renovation, as well as ensuring the existing habitat can fully support local flora and fauna.

This can be done by reestablishing plants, replenishing the soil community, and adding robophony into the soundscape to deter the presence of invasive species.

First Duplex Crystal Structure of Satellite III DNA Repeats

Erin V. Chen, Hyun Kyung Lee, Liliya A. Yatsunyk

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Satellite DNA – non-coding, tandem-repetitive nucleotide sequences – are predicted to play an important role in biological processes relevant to anti-cancer research and drug development. Satellite III is one of the most abundant satellite DNAs, composed of perfect $d(AATGG)_n$ repeats and found on numerous human chromosomes. Past structural studies have shown short sequences of Satellite III in hairpin conformations, while mutated variants have revealed a mixture of hairpin and duplex structures.

Here we investigate a perfect 4-repeat ATGGA sequence, which we refer to as S3, characterized through biophysical methods and solved through x-ray crystallography. Biophysical characterization shows that S3 folds into a stable monomolecular structure with B-DNA characteristics. However, the crystal structure of S3 was solved as an endless self-complementary duplex with notable non-canonical base pairing patterns, including a G-G intercalation and sheared A-G base pair. This is the first crystal structure of Satellite III repeats forming a duplex. Further concentration-dependent biophysical characterization emphasizes the previous monomolecular structure. Our results lend insight on the structural diversity of Satellite III sequences and inform the design of novel therapeutics targeted to specific structural features of DNA.

Age-dependent susceptibility to invasive *pneumococcal* infection in a novel *Mus musculus* model

Kenny "Kent" Chen[1,2], Kristen Lokken-Toyli, Ph.D.[2], and Dr. Jeffrey N. Weiser, M.D.[2]

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Globally, pneumonia remains a leading cause of mortality in children. Most pneumonia-related deaths, of which *Streptococcus pneumoniae* (*Spn*; the pneumococcus) is a major causative agent, occurred within the first 2 years of life. As a frequent colonizer of the upper respiratory tract (URT), carriage of *Spn* is typically asymptomatic; however, in young

children, colonization can progress to invasive pneumococcal disease. Clinical studies have shown that the incidence and duration of *Spn* colonization decreases with age; this inverse relationship between age and carriage suggests an age-dependent impairment of mucosal defenses required for efficient clearance of URT pathogens. Thereby, the improvement for overall childhood mortality substantiates a need to better understand the mechanisms that drive susceptibility to colonization and invasive disease in children.

In our study, preliminary research suggests that age-dependent differences along the epithelium— a barrier for immunity—drive susceptibility for respiratory infection in infants; bypassing the epithelial barrier through an intraperitoneal infection leads to similar rates of septic death, regardless of age. However, the host factors that mediate differences along the epithelial barrier are unknown. We have developed novel, clinically relevant infant (7-day-old) and adult (8-week-old) mouse models that recapitulate natural sites of acquisition by URT pathogens, using *Spn* as a model pathogen. **(Aim 1)** To study the effect of age, we intranasally (IN) infect infants and adults with an invasive 6a serotype *Spn* strain under 10^5 and 10^3 concentrates, respectively. Nasal lavages (i.e. nasal lumen) and whole nasal tissue homogenates (i.e. tissue-associated) were collected from each animal and their bacterial densities were quantified three days post infection. We confirm young age significantly predisposes to bacteremia (invasive disease), despite similar colonization levels in the URT. In accordance with our observations in infant mice, we observed a significant increase in transcripts expression of inflammatory and cell recruitment marker genes. Our data is telling of two interrelated mechanisms that may mediate mortality in infants: possible (1) inflammation-mediated tissue damage widening gap junctions between epithelial cells and (2) trafficking of viable pneumococcal cells by monocytes, macrophages, and neutrophils. **(Aim 2)** To investigate infant-host factors, we compare mortality, bacterial densities, and transcripts of wild type and $CD11b^{-/-}$ infant mice. Whilst typically known to facilitate clearance, our data suggests that host Cd11b infants is in fact detrimental to the survival of infant mice. Future studies need to assess the mechanisms by which host Cd11b promotes susceptibility.

Learn More:

Tracing Neurons in Deforming Brains: High-throughput, Large-volume Cell Registration Method

Kelly Finke, Zitong Chen, Tyler Boyd-Meredith, David Tank, Jeffrey Gauthier

The hippocampus plays a vital role in navigation. It is unclear, however, how the hippocampus supports spatial learning over long timescales in complex tasks. One limitation has been the ability to track neural activity for more than a few days or weeks. Even with two-photon imaging, which allows precise anatomical localization of recorded cells, brain deformations make it difficult or impossible to repeatedly image the same plane. Here, we introduce an analysis technique to track calcium activity in large populations at cellular resolution over months of training despite substantial deformations.

This technique is composed of two stages: 1) aligning each imaging session to a reference volume, and 2) identifying which cells were recorded on each day, using the reference volume to distinguish unique neurons. Though these processes can be largely automated, manual verification is required to ensure accuracy. To facilitate user inspection of the alignment and cell identification, we have developed a graphical user interface for each stage that allows for rapid verification and correction of the automated procedures. This analysis pipeline has allowed us to measure the activity of ~800 unique CA1 pyramidal neurons across 40 behavioral sessions spanning 90 calendar days. The results of this analysis are described in a companion poster. We anticipate our technique for tracking large populations could allow for recording longer timescales of activity in other brain areas as well.

First Duplex Crystal Structure of Satellite III DNA Repeats

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Satellite DNA – non-coding, tandem-repetitive nucleotide sequences – are predicted to play an important role in biological processes relevant to anti-cancer research and drug development. Satellite III is one of the most abundant satellite DNAs, composed of perfect $d(AATGG)_n$ repeats and found on numerous human chromosomes. Past structural studies have shown short sequences of Satellite III in hairpin conformations, while mutated variants have revealed a mixture of hairpin and duplex structures.

Here we investigate a perfect 4-repeat ATGGA sequence, which we refer to as S3, characterized through biophysical methods and solved through x-ray crystallography. Biophysical characterization shows that S3 folds into a stable monomolecular structure with B-DNA characteristics. However, the crystal structure of S3 was solved as an endless self-complementary duplex with notable non-canonical base pairing patterns, including a G-G intercalation and sheared A-G base pair. This is the first crystal structure of Satellite III repeats forming a duplex. Further concentration-dependent biophysical characterization emphasizes the previous monomolecular structure. Our results lend insight on the structural diversity of Satellite III sequences and inform the design of novel therapeutics targeted to specific structural features of DNA.

Determination of nonlinearity parameter B/A of liquids by comparison with solutions of the three-dimensional Westervelt equation

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Though nonlinear propagation depends upon the nonlinearity parameter B/A of the medium, it is often difficult to measure accurately. Thermodynamic methods often require high temperature and pressure excursions that can damage fragile molecules. Finite-amplitude methods often require unrealistic assumptions of ideal piston sources to account for diffraction effects. An alternative, described here, is to use the numerical solution of the three-dimensional Westervelt equation for weakly nonlinear fields (considering up to 10s of harmonics of the fundamental frequency), and to match measured harmonic generation with that for simulated media. In particular, we follow Jafarzadeh et al. (Ultrasound Med. Biol., 47(3),809-819, 2021) to find that the nonlinearity parameter of a liquid can be recovered by determining the best match between measurements and simulations of media with different B/A values. Ideal piston sources with radial symmetry are not required, only a high-spatial-resolution hydrophone scan of the near-field source plane. Other techniques to determine the nonlinearity parameter by comparing propagation models with experiments, such as Richard et al. (New J. Phys. 22, *063021, 2020*) may improve on earlier measurement methods.

Race Bias in Pain Perception: Effects of Race, Pain, Task, and Face Inversion

Chloe Savage and Catherine Norris

Racial minorities in the U.S. receive less adequate treatment for pain, and previous studies have demonstrated a race bias in pain perception, such that individuals exhibit a lower pain threshold to detect pain on White majority than Black minority faces. The current study investigated early contributions to this race bias in pain perception. Participants viewed upright and inverted houses (control) and faces (White/Black, no pain/pain) and indicated (a) when they saw an inverted face or (b) when they saw a face in pain. Analyses focus on the ability to detect a face in pain as a function of race and inversion, with the expectation that inverted Black faces in pain will in particular be difficult (lower accuracies, longer RTs) to detect, consistent with an early perceptual bias that contributes to overall race biases in pain perception. The current study provides behavioral data that will contribute to an ERP study focused on the N170 (i.e., face specific component) and its role in pain perception. Results from both studies are critical for understanding the stage at which race bias in pain perception emerges and may have important implications for the healthcare industry.

Artificial Second Language Acquisition from Stable and Unstable Transitions

Jino Chough with Ben Zinszer

Statistical learning is a widely-researched mechanism through which adults and children

are able to acquire artificial languages based solely on the statistical regularities of the speech. These artificial language learning studies are often used as an analogy for natural language acquisition, motivating researchers to investigate natural language phenomena, like bilingualism, through statistical learning paradigms. However, with two-language experiments, previous statistical learning studies show a strong overlearning, or "entrenchment" effect after a short time (approximately 5-10 minutes). This brief exposure to one language hinders the acquisition of another in consecutive auditory speech streams.

In this study, we sought to test the underlying causes of the entrenchment effect by manipulating the presentation of both languages in the speech stream. We hypothesized that an unstable learned first language (L1) would ultimately lead to better second language (L2) learning. On the first day of the experiment, participants were presented with L1 for 2:45 (m:s) for an initial exposure to the language. On the second day, for the "stable" experimental condition, L1 was presented in a 5:30 block, then a novel language (L2) was presented for the same amount of time in order to replicate the previous entrenchment effects. In the "unstable" condition, L1 and L2 were presented for the same total duration, but in blocks half as long (2:45), alternating three times.

Posttest two-alternative forced choice tasks were presented after the speech streams to judge how well participants had learned each language. Participants' response accuracy on the posttest showed that L2 acquisition was actually worse for the unstable condition than the stable condition, but in neither condition were participants on average able to acquire the second language. We discuss the results in the context of other similar studies and the potential future directions.

Exotic Physics in the Early Universe: Resolving the Hubble Tension with Various Early Dark Energy Scalar Potentials

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The Hubble Tension is currently one of the most significant sources of controversy in physics and astronomy. It describes a discrepancy in the Hubble Constant (H_0), the expansion rate of the universe today. H_0 is measured to be around 72 km/s/Mpc from observations of the universe around us. However, if we measure the Cosmic Microwave Background (CMB), which contains light from the early universe, and extrapolate based on our current understanding of cosmology, we predict that the value of H_0 should be around 68 km/s/Mpc. An intriguing explanation is that cosmologists are missing a factor in the expansion of the universe that would cause it to expand slightly faster than current models predict. Early Dark Energy postulates a scalar field in the early universe that temporarily accelerates its expansion and then dilutes away, leaving few traces. This summer, we investigated four potentials that may describe the dynamics of Early Dark Energy. We coded these functions into a program, AxiCLASS, that simulates the evolution of the universe given inputted theoretical dynamics and outputs the values of various cosmological constants. We found that all of our potential functions could produce an H_0 closer to 72 km/s/Mpc, given the right dynamical coefficient parameters. We are in the process of determining

which parameters are the most likely to be physically accurate and lead to the large-scale structure of the universe that we see today.

Assessing the Red-Sequence in the DESI LRG sample

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Our study aimed to understand the consequence of new data from the Dark Energy Spectroscopic Instrument (DESI) in clustering analysis of previous photometric surveys. To study how galaxies cluster, it is important to have a very large sample of galaxies, which we already have from previous cosmological surveys. Using new spectral data from DESI, we studied the consequences of errors in redshift measurements derived from photometric imaging. We also aimed to understand the accuracy of Kcorrections, a model that calculates magnitudes of objects from a specified reference frame, by comparing the results to magnitudes found through synthetic photometry, the calculation of total flux in a specified frame for a specific band by shifting the bounds of integration of an object's spectra. This comparison showed that the Kcorrect method is effective. Lastly, we used a newer method of red sequence galaxy selection by utilizing the infrared W1 magnitude and the r-W1 color, which was motivated by DESI's use of these colors to make their selection of large red galaxies (LRGs). This can give us insight on how galaxies of different mass and age cluster, particularly with the new selection method used by DESI. Preliminary results show that galaxies separate more cleanly when using the infrared band, as opposed to the traditional g-r color. From our selection of red sequence LRGs, the clustering amplitude is five times higher than the LRGs that lie outside of the red sequence.

Discovering Optimizations to Barn Owl Sound Localization through Neural Modeling

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Barn owls are masters at using their sense of hearing to pinpoint their prey in complete darkness. In particular, barn owls can use the difference in arrival times of sounds at their two ears to determine sound sources. These differences in arrival times are known as interaural time differences (ITDs). In our study, we modeled specialized neurons in a region of the barn owl brain known as the nucleus laminaris (NL). These neurons are sensitive to sub-millisecond ITDs. We sought to explore the model parameters and mechanisms that optimize ITD detection in barn owls. We also aimed to gain insights into the mathematical bases for owls' biological specializations. We accomplished this by using a system of ordinary differential equations to study the electrical dynamics of these neurons. We used a Hodgkin-Huxley type modeled with parameter values selected to describe barn owl neural dynamics (adapted from work by Go Ashida, Kazuo Funabiki, and colleagues).

We simulated spike rates while systematically varying parameter values to study how NLs encode ITD information. In doing so, we discovered a structural configuration in our model that optimizes sound-location sensitivity. Specifically, when we modeled the neuron as having two weak-coupled regions (or "compartments"), there was a larger contrast in neuron spike rates between sounds originating from different locations. Larger differences in spike rates between sounds of different origins enable owls to detect ITDs more successfully. Hence, we found that weakly coupled neural configurations led to improved ITD sensitivity.

Does being fostered with siblings prevent play behavior declines in Octodon degus?

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Our project focused on how fostering affects offspring play behavior in a social rodent species (*Octodon degus*). We were particularly interested in the hypothesis that being fostered with siblings can mitigate negative effects on play behavior. For our study, degu offspring were placed into one of three treatment groups: control, single cross-foster, and complete cross-foster. In the single cross-foster treatment, a degu pup was removed from its birth litter and placed with an unfamiliar litter and parents. In the complete cross-foster group, an entire litter was placed with an unfamiliar mother and father. For our control treatment, the entire litter remained with their biological parents. From Postnatal Day 24–28, we measured degu offspring play behaviors including play fighting, running/hopping, and resting. We predicted that levels of play would be highest in our control group, next highest in our complete cross-foster group, and lowest in our fostered pups within our single cross-foster groups. These data are applicable to humans, as degus also perform communal care.

SwatDB: Educational Database Management System Implementation

Matilda Ferguson and Seth Keim, advised by Ameet Soni and Tia Newhall

The SwatDB project carried out this summer consisted of designing and implementing missing layers of functionality in SwatDB. SwatDB is an educational database management system engineered to provide students with a platform to implement course concepts in lab assignments for the Swarthmore course Database Systems. Initial work on the system began in the summer of 2020, and the continued development of this tool during this past summer resulted in the creation of more meaningful lab assignments for the Database Management Systems course. SwatDB provides a well-tested codebase that facilitates the investigation of research questions about relational databases. As researchers, we are motivated by the ever-increasing prevalence and importance of databases in an era of increasingly data-centric computer use.

Efficiency is one of the most important qualities of a good database management system,

and we were able to take a critical look at how we can optimize our algorithms to increase speed and accuracy. However, because there are so many different use cases and potential access patterns for databases, there is not a single extensible solution. Through a redesign of the memory management layer of the SwatDB, modularity was incorporated such that the best memory management algorithm can be selectively chosen and seamlessly integrated within the rest of the system. In combination with the replacement algorithms we implemented and tested, we were able to run performance tests using the different algorithms under common database access patterns to assess the real impact of a feature like this.

Prior to this summer, SwatDB was missing the functionality to perform operations on the data. Manipulation of the data is a component that is central to the actual purpose of database management systems. We built and tested the relational operator layer from scratch, implementing key access operations, such as selection on a certain condition utilizing different algorithms. We placed a research emphasis on the join operation which combines data tables on a matching column in both tables and is an incredibly common but computationally expensive operation. Using an efficient versus an inefficient algorithm to perform this operation can be the difference of a few seconds versus a few years in computation. We implemented several different algorithms, including the brute-force solutions as well as heavily optimized solutions. We were able to run performance comparison tests on these, and notably, we saw meaningful results: the brute-force solution scaled to *days* compared to *seconds* for the partitioned solution.

This work will allow future students to grasp a more meaningful understanding of the material through hands-on manipulation, implementation, and testing of these algorithms. Widespread changes and critical expansion to the codebase further streamlined the functionality while also adding critical new elements. Future work will extend upon the codebase to incorporate parallel algorithms and functional lab assignments.

Dietary Preferences of Sea Urchins

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The variegated sea urchin (*Lytechinus variegatus*) is commonly used as model organisms for developmental biology and ecotoxicology. Their primary diet consists of seaweed, which can be challenging to obtain. To find alternative diets to maintain sea urchins in landlocked laboratories, we conducted two experiments to test if a terrestrial vegetable diet can be used in place of seaweed. First, we compared the consumption rate of cabbage and seaweed. The Japanese urchins *Strongylocentrotus pulcherrimus* had been shown to consume Chinese cabbage and develop larger gonads. After 4 weeks of feeding with cabbage and seaweed, the amount of food consumed and the growth over three weeks were comparable between the two diets, suggesting that the cabbage can be used as an alternative food source. We then tested if there is a preference among terrestrial vegetables with a two-current choice flume and presented the urchins with kale, spinach, cabbage, and seaweed in a pairwise manner. Interestingly, urchins showed preference towards kale and spent significantly higher time in the current with kale scent. These results show that

terrestrial vegetables can be used as alternative diets for lab-reared urchin and highlight the potential of developing more sustainable ways to utilize food waste in aquaculture.

Characterization of Influenza A Viral Matrix Proteins M1 and M2

Scout Hayashi, Sophie Engels, Chayanne Petit, and Dr. Kathleen Howard

The M1 and M2 proteins of the Influenza A virus are critical to viral reproduction. During the budding stage, M1 and M2 bind together which induces membrane curvature, nucleic acid transport, and eventually the creation of a new virus. Our project examines the native structure of these proteins using biophysical and biochemical characterization methods such as electron paramagnetic resonance (EPR), circular dichroism spectroscopy (CD), dynamic light scattering (DLS), and sedimentation assays. We were able to successfully purify two M1 constructs. DLS, and sedimentation assays show successful binding of M1 to M2. EPR shows a conformational change in M2 that results in a less mobile cytoplasmic tail when bound to M1.

Genome Assembly and Comparative Genomics of Kowalevskia oceanica

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In investigating evolution and development, tunicates are often used as model organisms due to their close taxonomic relationship to vertebrates and their concise and highly conserved genome despite millions of years of divergent evolution. *Kowalevskia oceanica* is an appendicularian (class within the Tunicata subphylum) that is especially unique in terms of its lack of a heart. Therefore, assembling the genome of *K. oceanica* and comparing it to those of other appendicularians, tunicates and chordates can show how a dramatic evolutionary change, the loss of a heart, impacts the genome of an organism. Here we show the work I did over the summer on assembling the genome of *K. oceanica*, identifying protein coding regions related to ancestral heart development and making sequence alignments for these predicted proteins in *Oikopleura dioica* (a well-studied appendicularian) and *K. oceanica*. To produce a draft genome assembly from Illumina paired-end DNA sequencing data I utilized numerous computational tools, such as FastQC (to check sequencing quality), Jellyfish (to count k-mers and determine genome size), Trimmomatic (to process reads) and MaSuRCA (to assemble the genome). Upon assembling the genome, I discovered that the *K. oceanica* has a genome size of 272 Mbp, which is around the midway point in comparison to the genomes of other tunicates. I am currently working on searching for the presence of genes that we know to be involved in heart development in appendicularians and ascidians (Mek, FoxQ, FoxF, Erg, Ets, Gata, Nk, Hand and Tbx) using BLAST, as well as improving the genome assembly quality by removing reads from contaminants and re-running MaSuRCA. Investigating differences between the cardiopharyngeal gene network of *K. oceanica, O. dioica* and other species, such as humans, could further our understanding of the constraints on evolution, or to

what extent the genome of an organism is able to change its structure and/or function in response to natural selection.

Conservation Through Soundscapes: Using Passive Acoustics To Study Endangered Baleen Whales Off the Coast of Falkland Islands

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Passive acoustic techniques are used to understand the spatiotemporal distribution of many species. Passive acoustic monitoring (PAM) is an important complement to visual data collection, which is limited by daylight and weather conditions. In the marine environment, continuous passive acoustic data collection can reveal important information about the presence of species in otherwise difficult to monitor areas. As part of a larger monitoring effort*, passive acoustic data were collected from bottom-mounted recorders to investigate the presence and distribution of two baleen whale species, sei whales (*Balaenoptera borealis*) and southern right whales (*Eubalaena australis*), in the South-west Atlantic Ocean off the Falkland Islands. Recorders were deployed at three sites in Berkeley Sound at depths of approximately 30-45 m over two years from December 2018. A generalized automated low-frequency detection and classification system (LFDCS, Baumgartner, 2011) was used to detect and classify potential call-types of southern right whales (upsweep calls), and sei-whales (downsweeps and L-calls) from the raw acoustic records. Putative detections were manually verified through visual and aural examination to determine whether they were true or false, and thereby log daily presence. Both target species were extensively acoustically detected, and their temporal distribution differed within Berkeley Sound. This study provides new insights on the seasonal extent of sei whale and southern right whale presence, demonstrating the value of PAM as a monitoring tool and contributing important information for the management and conservation of these species.

*Weir CR. 2018. A preliminary assessment of endangered sei whales (*Balaenoptera borealis*) in two candidate Key Biodiversity Areas in West Falklands. Falklands Conservation Report. Version 1.2, 128 pp.

How an Emergency Vehicle-to-Grid System Could Prevent Power Outages at Hospitals

REU Students: Justin Chai, Kyle McCoy, and Leena Rawashdeh
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Across the world, the percentage of electric vehicles (EVs) among ordinary passenger vehicles has increased dramatically. The increasing desire for alternative power sources

has led to the integration of these EVs with the power grid, a system known as Vehicle-to-Grid, or V2G. The subject matter of the experiments described in this paper pertains to simulations of V2G as a possible emergency power system that can offset the effects of sudden blackouts caused by power grid failures, natural disasters, or weather issues. To condense the project's scope to a more applicable size, a case study of Houston, Texas during February 2021's winter storm was used as a motivating example. The experiments conducted considered essential facilities such as hospitals as the location of the V2G systems. The study used the Mathworks 24 Hour Vehicle to Grid Simulink model [6] as a foundation before reworking the model in order to provide the simulated V2G the ability to completely offset any power needs during outage periods. By the end of the research program's duration, the reworked Simulink model features customizable driver behavioral profiles, adjustable daily load demand profiles from facilities, minimum EV penetration plots, power generation vs load plots, and many other capabilities. By using the simulated V2G and unique scenarios between two different Houston hospitals throughout a year, the plots revealed that V2G under a 24-hour outage would need a minimum EV penetration range of 55-84%. A more generalized conclusion of these 24-hour outage graphs would be the lack of viability of V2G as a long-term emergency power supply. However, by looking at plots concerning shorter outages under the same parameters, the simulation revealed that the minimum EV penetration level ranges from 16-24%. Furthermore, because the graphing function of the completed Simulink records the highest amount of minimum EV penetration needed for a 2-hour period at any given point in a day, a case for short-term viability of V2G can be made. Short-term implementation of V2G as an emergency power source showed much more promise as there were instances where the V2G was able to sustain power loads from 1-6 hours, depending on the time of day using EV penetration ranges achievable within the next decade. All in all, the testing of the small-scale implementation of V2G is the first step to realizing more systems that can aid in the search for efficient green power storage and supply alternatives.

Not all those who wander are lost: hippocampal strategies in navigational task learning

Eva Karolczak

The hippocampus is critical for navigation and learning goal-directed tasks. However, it remains unclear how hippocampal representations of space change over the course of learning, and the relationship between behavioral changes and physiological ones is poorly understood. To probe this distinction, we designed a task where mice learn to associate a water reward with a specific location along a virtual linear track. During every behavioral session from first exploration through expert performance, we imaged hippocampal reward cells and recorded licking as a behavioral metric of reward anticipation. Although accurate anticipation of the reward location was gradual, clustering analyses revealed discrete behavioral patterns interleaved throughout the learning process. Specifically, we observed licking patterns that may represent cue-based versus context-based strategies. These strategies were also characterized by distinct activity patterns of reward cells, implying that physiological changes in neural representation may underlie variability in behavioral strategy. More broadly, our results suggest that navigational learning does not proceed continuously in mice; rather, mice develop multiple competing strategies, each with their

own distinct hippocampal representation of the physical environment, over the course of task acquisition.

Effect of fostering environment on anxiety-like behaviors in a social rodent species

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The general goal of the study was to determine how fostering affects postnatal development of the degu (*Octodon degus*), a social rodent species. Specifically, we examined the hypothesis that fostering increases anxiety in juvenile degus. Degu litters were placed into three different treatment groups: single cross-foster, complete cross-foster, and control. In single cross-foster groups, one pup from one litter was swapped with one pup from another litter. For complete cross-foster groups, the entire litter was swapped, whereas no pups within control group litters were cross-fostered. We measured anxiety-like behaviors through three behavioral tests: the open field test, the light-dark box test, and the Barnes maze at 3-4 weeks of age. We predicted that cross-fostered pups would display higher rates of anxiety-like behaviors compared to control pups, and that single cross-fostered pups would display higher rates of anxiety-like behaviors than complete cross-fostered pups. Specifically, we predicted that compared to control pups, fostered pups would spend more time along the edges and corners of the Open Field Test arena, spend more time in the Dark vs. Light Box, and spend less time exploring the Barnes maze. As degus are social animals that practice both maternal and paternal care, these data will further inform how to reduce human stress caused by parental separation.

Carol Lorber Fellowship: Eldridge Commons Aquaponics System

Summer Research 2021 Report
Eva Krueger

This summer, I conducted a research project relating to Engineering and Environmental Studies, thanks to the Carol Lorber Fellowship. My research focused on the small-scale aquaponics system in Eldridge Commons, built by Terrence Xiao '20, and consisted of three main parts.

Firstly, I helped reactivate the system, which had been deactivated due to the COVID-19 pandemic. Then, I spent a large part of my summer prototyping an Arduino-based device that monitors the system's water quality to keep it healthy for fish, bacteria, and plants. I learned Arduino coding, researched different water quality probes, programmed, and hardwired everything together. The final device that I have created is one that regularly measures pH, dissolved oxygen, and conductivity of the fish tank. It also measures the water level of the sump tank. When any of the fish tank parameters are unhealthy or the sump tank water level is dropping too low, the program lights up an LED corresponding to the parameter that needs to be fixed. For each measurement taken, the Arduino saves the data to a .csv file on an SD card. If connected to a computer, it can also display the data in

the Arduino Serial Monitor.

Lastly, I conducted an experiment where I built a deep water culture grow bed and compared its efficacy with that of the existing flood-and-drain grow bed in cultivating lettuce.

Due to the inability to introduce fish to the system until late, my data was unfortunately largely inconclusive. The plants were observed as having many dying leaves and white discoloration, but the experiment did reinforce the importance of fish in an aquaponics system for providing plant nutrients and fueling their growth.

Conducting this summer research project taught me a lot about aquaponics as a potential technology for sustainable agriculture. I was able to interact with and rebuild a useful demonstrational system that will be available to future students as an educational tool. I was also able to build up my engineering experience and expertise through prototyping an electronics device, including coding its functionality, that can be further developed and used in larger, commercial aquaponics systems. This device could be essential in increased automation of water quality monitoring and management. Finally, I was able to investigate different types of aquaponics growing methods, and could compare the productivity of leafy greens in these different methods. This experiment could be useful to replicate with other plants, such as fruiting vegetables, in order to explore the commercial viability of aquaponics as a productive technology.

Light or Flight: Effect of light intensity on settlement behaviors of sea anemones

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Symbiotic relationships between cnidarians and their photosynthetic symbionts provide vital ecosystem services. To date, many studies have focused on the photobiology of corals. Earlier works have illustrated that light intensity and spectral property affects settlement of coral larvae. Here, we investigate if a similar pattern occurs in adults of aposymbiotic (*Actinia equina*) and symbiotic (*Exaiptasia pallida*) anemones. By manipulating light intensity, we tested whether light affects where sea anemones settle and if the presence of symbionts affects the sea anemones' movement. Time-lapse videography revealed that on average, *A. equina* did not respond to low light intensity (~5.33 μmol m^{-2} s^{-1} and ~12.33 μmol m^{-2} s^{-1}), i.e. remained stationery. They exhibited shade seeking behavior in moderate light intensity (~22.67 μmol m^{-2} s^{-1}) and remained mostly sessile with tentacles fully retracted in high light intensity (~33.67 μmol m^{-2} s^{-1} and ~39.33 μmol m^{-2} s^{-1}). In contrast to *A. equina, E. pallida* generally tolerated high lighting cues: individuals exhibited shade-seeking behavior at light intensity as high as 43.33 μmol m-2 s -1. The response of *E. pallida* varied between individuals with high quantum yield (Fv/Fm > 0.7) and those beneath the threshold (Fv/Fm ≦ 0.7). *E. pallida* with high quantum yield generally spent more time in the shade than in light. This difference suggests that abundance of photosymbionts influences light response behavior. This association between symbiont and host behaviors supports the use of *Exaiptasia pallida* as an ideal surrogate to study photobiology of coral. The intraspecific variations observed could account for differences in the spatial distribution of

Exaiptasia pallida and *Actinia equina* in the field.

A method for eliminating light contamination in optical measurements of neural activity

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Much of our insight into brain function has come from observing activity in populations of neurons. One common technique, two-photon imaging, measures the light emitted by fluorescence indicators that become brighter when neurons are active. Due to the tight packing of neurons in the brain, it is important to carefully distinguish the light coming from each cell. To investigate the accuracy of commonly used methods for extracting neural activity from imaging data, we applied them to a standard simulated dataset where the right answer is known. We found these methods were highly susceptible to light contamination and underestimated each neuron's fluorescence by a factor that varied over two orders of magnitude (0.001 to 0.5). Importantly, these values were different for each cell. To address this problem, we created a quantitative model of light sources in two-photon imaging and developed a method to correct the estimates of fluorescence. When applied to the simulated neural data, our method performed nearly perfectly for cells clearly in the imaging plane (on average, 1.10 times the true fluorescence value, SD 0.27). In real data, activity estimated by our method was 55 times greater than that of standard methods, suggesting that published studies could contain significant errors. This result shows that our method enables more accurate and consistent measurements of fluorescence across neurons. These measurements could provide important insights into neural populations, such as revealing new subclasses of cells, or distinguishing patterns of activity that were previously obscured by contamination.

Geomorphology of Serpentine and Carbonate-Bearing Terrains in Nili Fossae, Jezero Crater, and Gusev Crater

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Carbonates have been detected in several locations on Mars, including Nili Fossae, Jezero Crater, and the Comanche outcrops of the Columbia Hills. Carbonates are intriguing for what they could reveal about potential habitability of past environments; however, their exact formation mechanisms remain ambiguous. Observations support a range of mechanisms, such as precipitation falling on and altering hot olivine ash, heated water altering existing rock, water near the surface interacting with rock that has transformed into serpentine, or short-lived lakes altering surrounding rock. The associated mineralogy of carbonate-bearing terrain, such as the serpentine deposits detected in Nili Fossae and Jezero, can help constrain the origins of the carbonates. This study examined CRISM (spectroscopic) and HiRISE (high-resolution) images of analogous serpentine and carbonate deposits in Nili Fossae and Jezero Crater to identify common characteristics of

serpentine-carbonate terrains. The morphology of these terrains was then compared to that of the Comanche carbonates to constrain the Comanche outcrops' formation mechanism. We found that many serpentine-carbonate areas in Nili Fossae and Jezero share similar fractured terrain and spectral signatures. While the Comanche outcrops display possible fracturing, their morphologies do not produce conclusive evidence to support the presence of serpentine in the Columbia Hills or suggest commonalities between the sites' aqueous histories.

Unique DNA Structures in the HRAS Oncogene Promoter

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I-motifs are a non-canonical secondary structure of DNA formed by cytosine-rich strands. iHRAS is an I-motif-forming 27 base-pair sequence extracted from the HRAS gene in the human genome. By crystallizing 5-bromocytosine-substituted versions of iHRAS, we were able to solve the crystal structure using Single Wavelength Anomalous Dispersion (SAD). The crystal structure reveals iHRAS folding as a dimer, producing two i-motifs. This dimer is intramolecularly stabilized by pi-stacking between nucleotides and non-canonical base pairings.

Ambiguity in Object Naming and Lexical Categorization in English Monolinguals

Gabrielle Ma, Professor Benjamin Zinszer

There are many factors involved in naming objects that affect the difficulty of the process, like the typicality of an object to a particular category and our familiarity with the concept. Most previous studies have focused on dominant examples of a category to minimize this difficulty. On the other hand, we focused on varying ambiguously categorized objects to accurately represent the real life scenarios language-users encounter. Our goal is to better understand the cognitive underpinnings of lexical categorization.

English-monolingual participants in the U.S. were asked to name images of objects and rate the typicality of the image with the name provided by the participants for 150 images from 5 broad domains (clothing, vehicles, dishes, tools, and furniture). Images were selected from a previous study of 407 collected in 2013 with monolingual undergraduate students in the US and China. Specifically, the 150 images were weakly or uncorrelated in naming difficulty between English and Chinese samples. In other words, objects easy to name in English were hard for Chinese participants to name and vice versa.

We estimated dominant names reported for each image, percent name agreement across participants, and typicality ratings of each image to the dominant name. As in the previous study, there was a wide variation in naming agreement (40-100%) and typicality ratings (1.5-4).

We found that the dominant names in the current sample of English participants matched the 2013 sample (91%) and name agreement was moderately correlated between current

and previous English samples while remaining uncorrelated with the previous Chinese sample. This finding suggests new norms are consistent representations of English monolinguals' object categories. Further, we compared typicality ratings when estimated only from participants who responded with dominant names (conditional typicality) versus typicality ratings from participants who responded with any name given to the object (average typicality). We found low correlations between conditional and average typicality, demonstrating that typicality of an object is not the only property of the object, but depends on the name given by the participant.

These measures of ambiguity and naming difficulty are reliable properties of a language and are not the same between Mandarin and English. Further research with Mandarin English bilinguals and Mandarin monolinguals can explain how language-specific category knowledge from their first language influences learners' difficulty in naming objects in their new language.

An Analysis of Discrete Free Boundary Problems

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The standard (continuous) Alt-Caffarelli energy functional is given by $\mathcal{E}[f] = \int_D |\nabla f|^2 dx + |\{f > 0\} \cap D|$ for a function f on a connected open set D in Euclidean space. Minimizers of this functional give rise to what is known as the Bernoulli free boundary problem. We study a discretization of this energy $J_G[f] = \sum_{\{x,y\} s.t. x \sim y} (f(x) - f(y))^2 + \#\{f > 0\}$ where G is a graph and f a function on the vertices of G. We study local and global minimizers of this discretized energy functional, proving existence, giving strategies to construct minimizers, and addressing questions of uniqueness.

Characterization of the DH475 cooperating antibody and its interaction with the HIV-1 spike

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HIV evolves very quickly, so approaches to design an effective vaccine that elicits protective antibodies have thus far been unsuccessful. Current HIV vaccine design efforts seek to elicit broadly neutralizing antibodies, unique antibodies that target many viral variants, by first eliciting their precursors through prime-boost regimens. To guide vaccine design strategies, we are analyzing a cooperating antibody, called DH475, which exerted

pressure on HIV to evolve in such a way that it became sensitive to the DH270 broadly neutralizing antibody lineage. This study aims to elucidate how DH475 binds to the HIV viral spike and identify how DH475 facilitated the development of DH270 broadly neutralizing antibodies. We obtained a 2.90Å crystal structure of DH475 in complex with the Man9 glycan, and used site-directed mutagenesis coupled with biolayer interferometry (BLI) and protein-protein docking to characterize how DH475 interacts with Env. These investigations revealed a glycan-dependent epitope, and docking analyses identified an unorthodox binding mode in which the DH475 framework and constant regions participate in binding. While further confirmation of DH475's binding mode is required, our findings indicate an overlapping epitope between the DH270 lineage and DH475, consistent with its cooperative neutralization ability.

Patterns of HSATII Expression in Clonal U2OS Cells

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Previously characterized as "junk DNA," Human satellite II (HSATII) is a repetitive non-protein-coding sequence that comprises roughly 2% of the human genome. While transcriptionally silent in healthy human cells, HSATII has been found to be highly expressed as a noncoding RNA in several cancer cell lines. The dynamics of HSATII expression, like that of many satellite sequences, remain largely unexplored. Focal accumulations of HSATII RNA tend to be highly variable in both their size and number in a given population of cultured cancer cells. This heterogeneity of HSATII expression may be attributable to the formation of distinct cell lineages. This study examined patterns of HSATII expression in two distinct clonal lines of U2OS cells. To compare whether the clones differ in their timing and levels of HSATII expression, cells from each clonal line were stained with PCNA antibody, a marker for S-phase, and scored for HSATII expression. Our findings suggest that clonal populations of U2OS cells differ in their average size and number of HSATII foci, but share predominant expression of HSATII in S phase of the cell cycle. Although further assessment of HSATII expression in distinct cell lineages is necessary, these findings offer preliminary support that expression of HSATII differs between clonal lines of U2OS cells and is dependent on both the cell cycle and cell lineage.

SilentTalk: Ultrasonic Lip Reading

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Ultrasound has many practical applications in the field of acoustical engineering. At its core, ultrasound is high-frequency sound that is inaudible to the human ear. Our project, Silent Talk, proposes to use ultrasound as a means for lip-reading technology. The goal is to create a device that is capable of allowing people to have silent cell phone conversations. The device, which will consist of ultrasonic transducers, will continuously emit ultrasonic waves and reflect them off of the user's mouth. These reflected signals will be translated into speech using a trained neural network.

Ultrasound has two important properties that are relevant to lip-reading; its ability to capture mouth and lip movements, and its ability to distinguish between changing facial

structure. By running ultrasonic sweeps from a tweeter speaker, ultrasound can be reflected off of a surface and recorded by an ultrasonic microphone. When analyzed via MATLAB, these signals reveal important information such as structure and movement of objects. For reflection off of irregular surfaces, such as the face, a neural network can be used to analyze large signal sets, where patterns are more difficult to discern. Neural networks will serve as the basis for creating a continuous lip-reading device.

Qualitative Piping as Means to Investigate Immigrant Identity

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In this project, we focus on immigration as a critical life event that can propel individuals into a sense of identity. In the United States, roughly 14% of the population is immigrant (American Immigration Council, 2020), belonging to a large and growing class of people. To the detriment of research in our field, studies on immigrants' identity have focused on their ethnic or and national belonging. In order to address this major gap in literature, we collected open-ended qualitative data from immigrants about the ways the migration process has shaped how they view themselves and how they perceive others. With a sample of 217 first- and second-generation immigrants, we used piping to investigate private regard, the way immigrants view their group as a whole. (Harvey et al., 2012, Sellers et al., 1997). Our results indicate trends and patterns in immigrants' self-concept, with praise for work ethic and grit reappearing and references to poverty and alienation included to a lesser extent.

Analysis of the interactions between the HIV-1 Spike and the F7-22 "cooperating" antibody

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Broadly neutralizing antibodies (bnAbs) are promising for HIV-1 vaccine design because they target highly divergent strains of the virus. However, attempts to elicit bnAbs have not been successful because of their long maturation pathways and high mutation frequencies. Thus, the design of an effective vaccine to elicit bnAbs will require an understanding of the co-evolution process between the virus and antibodies in a host. In one HIV-1 infected patient called CH848, the elicitation of a bnAb lineage called DH270 was preceded by a cooperating antibody lineage, of which DH272 was a member. This antibody was observed to neutralize, or prevent infectivity, of the initial infecting virus, called the transmitted founder (TF). We characterized an antibody antigen binding fragment (Fab) closely related to DH272, called F7-22, and its interactions with the TF spike protein, called Env, from patient CH848 using negative stain electron microscopy, molecular modeling, and binding kinetics. Data implicate the Fab CDRH3 and CDRL1 loops and the Env V1/V2 loops as important for complex formation. Further work is needed to develop a more complete model of this interaction and a rationale for the mechanism through which DH272 acts as a cooperating lineage.

Discovering Young Eclipsing Binaries with TESS

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Current models describing how young, low-mass stars evolve before reaching the main sequence diverge from one another and are inconsistent with measured stellar properties. A larger sample of young, low-mass stars with well-determined properties is integral to constraining these models and making them more accurate. Since properties of eclipsing binary systems can be determined through observations alone – without assumptions based on models – they are useful in building such a sample. In this project, we searched TESS data for previously unstudied young, low-mass eclipsing binary systems. We created and examined light curves for 398 targets flagged as known young, low-mass spectroscopic binaries or radial velocity variables using cutouts of TESS full-frame images. From this initial search, we identified nine eclipsing binary candidates. We have begun the process of modeling these nine systems. The next steps for this project include taking additional ground-based observations of each target in our current sample and expanding our search for young, low-mass eclipsing binaries to greater numbers of targets.

The extension of a G-tract alters G-Quadruplex folding in a disease causing mtDNA sequence

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The folding of all DNA is crucial to prevent damage and regulate transcription of genetic code. Due to the origins of mitochondria as independent bacteria which integrated into cells, their genetic code is partially stored in nuclear DNA, as well as in separate mtDNA. In addition to the canonical helix structure with A-T and G-C base pairing, G-rich segments of DNA and mtDNA can fold into alternative, G-Quadruplex (GQ) structures. GQs contain planar G-tetrads that are stabilized by the Hoogsteen-hydrogen bonding of guanine bases, and which stack due to pi-pi bonding. The folding topology and stability of GQs is sequence dependent.

Mitochondrial disease-causing mutations that extend the G-tracts in sequences which are able to fold GQs could alter the structural protection of mtDNA. Biophysical characterization techniques and native PAGE gels were used to investigate the folding structure of an mtDNA sequence from the reverse complement of m.15516-15545, and the same segment with pathogenic polymorphism m.15519C, which extends the fourth G-tract. Stable parallel character and increased thermal stability in the pathogenic sequence suggests the folding of a four tetrad GQ, while hybrid character and lower melting temperatures for the non-pathogenic sequence suggest the folding of a three tetrad GQ.

Mathematical Explanation in Science

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Through the analysis of several natural phenomena, our collaborative research on mathematical explanation in empirical science provided examples of the intersection of nature, science, and mathematics. I researched multiple case studies and started with the use of Latin squares in agronomic research. Latin squares are tables of $n \, x \, n$ values containing n different characters arranged in such a way that each character appears exactly once in each row and once in each column. Due to their ability to randomize entries in a balanced fashion, they're used in experimental design for agricultural, medical, educational, and psychological research, as well as for taste testing and in technological applications. I then investigated the geometry of Buckminsterfullerene, a spherical molecule made up of sixty carbon atoms that's noted for its stability, superconductivity, and ferromagnetism, in addition to its cage-like structure and symmetry. Group theory and Euler's formula help explain the unique structure and properties of the molecule. We also explored the sequencing of sunflower seeds in seed heads; research shows that seeds form a distinct spiral pattern that can be described by the Fibonacci sequence and golden ratio. The seed pattern helps optimize space and the absorption of sunlight because the golden angle guarantees that each seed receives the maximum exposure to light without casting shadows on neighboring seeds. The placement of seeds is also driven by growth hormones, and by maximizing the amount of seeds packed into an area, sunflowers increase their chances of reproductive success. Lastly, I researched how certain factors influence the shape of avian eggs and examined the patterns and geometry of wound healing to analyze how wounds of certain shapes heal at different rates.

Applying Facial Recognition Techniques Towards Non-Intrusive Mask Detection

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The changing landscapes due to COVID-19 urge for the development of new solutions and advancements in Data Science such as advanced neural network algorithms which can make us more vigilant thereby preventing possible contamination. This study looks at the existing Baum-Welch algorithm for facial recognition - which is statistically based - as well as the underlying representation and segmentation of images using Linear Algebraic techniques. Facial recognition is based on the idea that the set of parameters defining a face will be unique for every person. These parameters created using an Embedded Markov Model can be manipulated by changing the observation density functions to suit different criteria. Through the study, new equations are reached which are then implemented in a real-time code in which a face is treated as an intrinsically two-dimensional recognition problem processed using a 3-layered neural network architecture. The goal of the algorithm is to non-invasively isolate individuals in a frame and detect whether they are wearing masks, as criteria to generate a metric representing

COVID-safeness at that location. The computational approach to perform deep learning is motivated by both physiology and mathematical theory, as well as by practical requirements. The current method of face mask detection is a two-step process where the first step is to perform face detection and then to apply the face mask detector to every face detected. A large training database consisting of 1,376 images belonging to two categories - with mask and without mask - was chosen to obtain a result and allow the neural network to assign accurate biases and generate a detailed cost function to output the confidence value. The program is run on a python interpreter using the OpenCV and tensorflow.keras packages. The model is analyzed by both realistic and generated data. The algorithm detects masks with a confidence level consistently above 90%. The findings of this study show that a probabilistic automaton has high efficiency in object-detection. This study implies large scope in the real-world applications in the field of facial recognition which has seen rapid growth over the last two decades.

The Magnification Factor: Impact of Financial Assistance in Health Care

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This health economics paper examines the impact of financial assistance to low-income patients suffering from chronic disease, based on a live study conducted of Lupus patients. Lupus is an autoimmune chronic disease that affects women's internal organs leading to death if not managed properly. Volunteering with low-income patients for three years, it was observed that they avoided medication and doctor visits due to the costs involved. The poor compliance resulted in poor medical health. This study evaluates and quantifies the increase in medical compliance, health benefits, Quality of Life (QoL), and motivation of the beneficiaries based on financial assistance provided through a randomized control trial. Based on a questionnaire modeled on the WHO QoL questionnaire, patients were interviewed on a recurring basis with the outcome being assessed during several stages of receiving funding. The QoL represents an indicator of health, comprising physical, mental, social and environmental aspects. The Magnification factor, M, is represented by the combined effects of factors of Compliance, QoL, and Happiness. The findings show that the benefit gained by patients is larger than the financial assistance received. There is a magnification in absolute value of aid beyond the monetary benefit, due to a greater will to adhere to the treatment. Further, it was observed that medication compliance and QOL have a strong correlation. One potential reason for this is that patients with high medication compliance tend to be living disciplined and regular lives, which implies they are more likely to regulate their medication compliance and administration. The experiment was based on the initial finding that compliance and medical health are positively corelated, and therefore a corollary to the above statement, would be to closely monitor changes to the QoL to identify patients whose medical health might be deteriorating. The model proposed through the paper is able to predict patients with low QoL in advance, who can then be identified, reached out to and helped before their health condition becomes critical. The study also proposes studying composition of benefits gained, so as to disperse and allocate funds in a targeted manner in health care and related areas. Lastly, an important outcome of the study is that it creates a quantified argument for the need for free access to health care.

Effect of pins on force distributions in frictionless jammed systems

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Whether you are scrambling over boulders on a hike, making your way across a sandy beach, or agonizing over a stubborn saltshaker, you are engaging with granular materials—large collections of macroscopic, rigid particles—on a regular basis. Granular materials are in many ways as much a staple in our everyday lives as conventional solids, liquids, and gases, but their behaviour eludes a simple explanation. Generally defined as a large collection of particles over 100μm in diameter, granular materials interact primarily through repulsive contact forces. At this length scale, particles do not exhibit Brownian motion as is common in fluids, and thus systems cannot consistently reach thermal equilibrium. Varying particle radii, localized force interactions, and failure to equilibrate combine to make disorder a key aspect of these materials. Yet granular materials can exhibit both solid and fluid states of matter under different conditions. Our research concerns itself with granular materials in the "jammed" or solid-like state, and how these systems deviate from the typical properties of solid matter. We build on existing research by examining the behaviour of jammed states in the presence of pins, which are fixed obstacles placed in a jammed configuration, and how the introduction of pins alters the distribution and geometry of contact forces in the jammed system. A more complete understanding of how granular materials jam has myriad applications, from cement mixing to the physics of jammed cancer cells.

Aluminum Complexes Implementing Redox Active Bidentate Ligands

Omar Saleh

A Collaboration with Prof. Chris R. Graves

The development of aluminium complexes implementing redox-active ligands has the potential to significantly broaden the reaction chemistry of the element through expansion into redox-based chemistries. Herein we report the synthesis of aluminium coordination complexes implementing redox-active nitroxide-based ligands. We will specifically discuss the coordination chemistry of *N*-tert-butyl-*N*-(2-R-pyridyl)hydroxylamines (^{R}pyNOH; R = H and MeO). Synthetic details and characterization (1H and 13C NMR spectroscopies, X-ray diffraction) data for the aluminium complexes supporting one, two, and three ^{R}pyNO ligands will be presented. The electrochemical characterization of the complexes will also be presented. Finally, we will discuss the reaction chemistry of the complexes with various Lewis acids

Modeling the Brγ Emission Line in CTTS in Taurus

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The structure and evolution of protoplanetary disks gives us a look at solar systems that are in the process of forming. As such understanding these systems can help explain

how our solar system and home planet came to exist in their current configurations. Accretion in protoplanetary disks is an important process which influences how they evolve. In T-Tauri stars, the magnetic field of the star truncates the disk before it can make direct contact with the star's surface. Instead, material flows from the inner regions of the disk along magnetic field lines to the stars surfac. Our research seeks to gain a better understanding of this process by modeling the Brγ line of hydrogen which is a known tracer of accretion and whose emission is thought to originate from these accretion flows. We used a model which simulates the magnetospheric accretion process in young stars and used that to try to recreate the Brγ profiles that were observed by the near infrared spectrometer IGRINS of thirteen objects in the Taurus star forming region. In the end we were able to model accretion quite well in these objects and furthermore, we recently obtained high quality spectra for all the remaining objects in Taurus and hope to apply this technique to model those objects as well.

Modeling Bilingual Semantics Using Word-Embedding Models and Object Naming Tests

Wendy Wen , Selena She, Gabrielle Ma, Professor Benjamin Zinszer

In this project, we try to model lexical semantics in Chinese-English bilingual vs. English monolinguals by 1. doing a correlational analysis using word-word similarity rating 2. developing new algorithms that align semantic spaces in different languages.

A Principal Component Analysis of Happiness in Mexico

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Alternative methods of measuring happiness and methods of indexing it have over time become more popular as the economic centered happiness paradigm based in GDP per capita and other such values has been challenged more. As a part of my summer research I investigated the use of principal component analysis as a unstructured statistical method to index different methods of measuring happiness and to value their internal consistency. I worked in collaboration with other students and professionals in a virtual webinar hosted out of Guanajuato Mexico. We utilized two data bases, one of purely subjective health data labeled the BIARE and conducted by INEGI and a synthesized state level variable database based on components of happiness as listed by the OECD. After applying a PCA model to our database we compared the results to each other and handmade models. We then did a more in depth analysis of the loadings from the PCA and compared our data based responses to a real life practical and theoretical understanding of the state of happiness in Mexico.

Anxiety Sensitivity and Disgust Sensitivity Predict Blood-Injection-Injury Phobia Symptoms in Individuals with Dental Anxiety

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Anxiety sensitivity (AS) and disgust sensitivity (DS) are transdiagnostic vulnerability factors for anxiety. Both correlate with blood-injection-injury (BII) phobia symptoms in several studies; however, there is ambiguity about their relative contributions. For example, whereas Cisler et al. (2008) found that both AS and DS predict BII symptoms above and beyond each other, Winder et al. (2021) report that AS no longer predicted BII after controlling for DS. Critically, both studies used unselected non-clinical samples. Furthermore, although DS reliably predicts BII in studies that do not account for AS, this may be limited to domain-specific DS (e.g., Bianchi & Carter, 2012; de Jong & Merckelbach, 1998) rather than DS more broadly.

In the *DSM-5* (APA, 2013), dental phobia is a type of BII phobia, and although there is reason to question the validity of this classification, most individuals with dental phobia have BII phobia (e.g., De Jongh et al., 1998). We therefore examined AS (Anxiety Sensitivity Index; ASI) and DS (Disgust Emotion Scale; DES) as separate and simultaneous predictors of BII symptoms (Injection Phobia Scale; IPS) in a sample of 54 participants who scored above a clinical threshold on a validated measure of dental anxiety (Modified Dental Anxiety Scale) and who represented a wide range of BII severity.

BII severity correlated with ASI (r = .40, p = .004) and with DES (r = .47, p < .001). We regressed IPS on ASI (centered), DES (centered), and their interaction. The model accounted for 28% of the variance in BII severity, F (3, 45) = 5.86, p = .002. Both ASI (β = .32, t = 2.07, p = .045) and DES (β =.35, t = 2.54, p =.015) independently predicted IPS. Their interaction was not significant (p = .379).

Disgust sensitivity about injections and blood draws may simply be a proxy measure of BII fear, and in fact the DES injections and blood draws subscale correlated strongly with IPS (r = .75, p < .001). We therefore omitted the DES injections and blood draws subscale and created a composite score of non-BII-related DS using the DES mutilation and death, animals, rotting foods, and smells subscales. BII severity correlated with this composite (r = .33, p = .017). We regressed IPS on ASI (centered), non-BII-related DES (centered), and their interaction. Together, the predictors accounted for 22% of the variance in BII severity, F (3, 45) = 4.23, p = .010. Only AS independently predicted BII symptoms, β = .40, t = 2.60, p = .013. Neither non-BII-related DS nor the interaction between AS and DS were significant (ps > .163).

In a clinical sample of individuals with dental anxiety and elevated BII fears, AS and DS both independently predicted BII symptoms. These results stand in contrast to recent findings in a non-clinical sample (Winder et al., 2021). Moreover, in contrast with some studies that implicate only domain-specific DS in BII phobia, our findings implicate domain-general DS as well, although not after accounting for AS.

Quality of Life in Universal Screening-Identified Pediatric Celiac Disease

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Celiac disease (CD) is a common autoimmune disorder in the United States (US) only treatable by a strict gluten-free diet (2). Undiagnosed CD causes increased morbidity, thus early identification is imperative. Autoimmunity Screening for Kids (ASK) is the first US mass pediatric screening study for CD and type 1 diabetes mellitus. ASK participants represented diverse racial/ethnic backgrounds (n=9934, 8% Black, 50% Latinx). The Outcomes of Screening-Identified Celiac Autoimmunity Research (OSCAR) study examines medical and psychosocial outcomes of ASK participants with confirmed CD. Here, we investigate changes in health-related quality of life (HRQoL) pre- and post- CD diagnosis in an OSCAR cohort (n=44). Participants included 19 screening-identified children with CD (Age M: 11.46, SD: 3.94, 39% male, 84% non-Hispanic White) with completed measures. Data were collected through the 23-item Pediatric Quality of Life Inventory (PedsQL), which assesses physical, emotional, social, and academic functioning. The PedsQL was administered prior to confirmation of diagnosis and 12 months post-diagnosis. A paired samples t-test evaluated differences in PedsQL scores pre- and post- CD diagnosis using both child and parent reports. Parents reported that their child's HRQoL significantly improved from pre- to post- CD diagnosis, $p<0.05$, with statistically significant increases in physical, emotional, and academic functioning, $p<0.05$. Children with CD reported a significant improvement in social and academic functioning, $p<0.05$ as well as overall HRQoL, $p<0.05$. Children screened for CD without current cause, and subsequently diagnosed, show improvements in self- and parent proxy-reported HRQoL from pre- to post- diagnosis, suggesting that participating in the screening process may result in positive outcomes. Universal screening presents a cost-effective technique to identify all cases of CD that has the potential to decrease diagnostic delay and accompanying morbidity levels.

Membranes and Mitosis: A New Understanding of How Membrane Receptor Trafficking During Mitosis Affects Cell Fate

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Membrane trafficking is a process that utilizes membrane-bound vesicles, or endosomes, as transporters to move and distribute protein. Up until recently, it was thought that membrane trafficking did not occur during cell division. Thus, fundamental aspects of mitotic trafficking remain poorly characterized. We utilize the invertebrate chordate *Ciona intestinalis* to study the potential mechanisms that dictate membrane trafficking during mitosis. Our previous findings indicate that endosomal trafficking and lysosomal degradation of fibroblast growth factor receptors (FGFRs) during asymmetric division plays a key role in the differential specification of daughter cells (Cota and Davidson, 2015; Cota et al, 2021). Based on these results, we hypothesized that the cytoplasmic domain of FGFR

dictates differential degradation. To investigate this hypothesis, we generated various FGFR/Cadherin chimeras which lack segments of the cytoplasmic domain or contain specific point mutations in this region. When compared to an FGFR chimera with an in-tact cytoplasmic domain, removal of the c-terminal region of the cytoplasmic domain results in a notable decrease in degradation. Interestingly, addition of this c-terminal segment to extracellular Cadherin is sufficient to induce internalization. These findings suggest that the cytoplasmic domain plays a role in both internalization and degradation of FGFRs during mitosis, which ultimately promotes asymmetric fate specification of the daughter cells.

Crystal structure of LiFePO4 and FePO4 battery cathode materials at high temperatures

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I studied how lithium iron phosphate ($LiFePO_4$), a battery cathode material, and its counterpart iron phosphate ($FePO_4$) change structure at high temperatures. LiFePO4 is a common material in rechargeable lithium-ion batteries, which power everything from laptops to electric cars. By learning more about the material, we can inform the improvement of battery design and performance. My project focused on determining whether and how the arrangement of molecules changed in LiFePO4 and FePO4 as the temperature increased. I used Rietveld Refinement, a least-squares approach of trying different parameters to see what will best fit the data, to analyze our neutron powder diffraction data with the software TOPAS Academic. I found that the materials LiFePO4 and FePO4 do not undergo any major structural changes at temperatures up to 400 degrees Celsius. This indicates that, as expected, I did not find any other crystal structures that the cathode material might form over a battery's lifetime, helping explain why LiFePO4 makes a reliable battery. I also found that the expansion of these materials under heating may not be linear: the materials may expand more with increasing temperature, and along one axis FePO4 may even contract initially while heating. This difference in thermal expansion could cause breaks in cathode crystals and possibly cause the battery to be less efficient after being heated. Further testing should determine whether this is true.