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Abstract Book

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JSHS is a Department of Defense sponsored STEM program (U.S. Office of the Secretary of Defense and the U.S. Departments of the Army, Navy, and Air Force) that encourages high school students to conduct original research in the fields of science, technology, engineering, and mathematics (STEM) and publicly recognizes students for outstanding achievement.

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National Junior Science and Humanities Symposium



Program Objectives

- Promote research and experimentation in science, technology, engineering, and mathematics (STEM) at the high school level.
- Recognize the significance of research in human affairs and the importance of humane and ethical principles in the application of research results.
- Identify talented youth and their teachers, recognize their accomplishments at symposia, and encourage their continued interest and participation in STEM.
- Expand the horizons of research-oriented students by exposing them to opportunities in STEM within the Department of Defense, academia, industry, and government.
- Increase the number of adults capable of conducting research and development.



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Section I

Directors of Regional Symposia

Academic Year 2024-2025

Alabama

Dr. Mark T. Jones
Alabama Academy of Science
Birmingham, AL

Alaska

Dr. Javier Fochesatto
University of Alaska Fairbanks
Fairbanks, AK

Arizona

Dr. Kendrick Buford
The University of Southern
Mississippi
Hattiesburg, MS

Arkansas

Dr. Jessica Conry Young
Dr. Amber Harrington
Arkansas Tech University
Russellville, AR

California Northern

Dr. Sybil Yang
San Francisco State University
Lam Family College of Business
San Francisco, CA

California Southern

Dr. Mahdi Yoozbashidadeh
Dr. Joseph Kalman
California State University Long
Beach
Long Beach, CA

Chicago

Dr. Kendrick Buford
The University of Southern
Mississippi
Hattiesburg, MS

Connecticut

Dr. Brittany Knight
Dr. Victoria Schulman
UConn Health, CT AHEC (Area
Health Education Center)
Farmington, CT

DoDEA Europe

Mr. Galen Tate
Dept. of Defense Education
Activity Europe
APO, AE

DoDEA Pacific

Mr. Blake Sims
DoDEA Pacific Region Schools
APO, AP

Florida

Ms. Danae Perry
Dr. Michael Bowie
University of Florida - Center for
Precollegiate Education and
Training
Gainesville, FL

Georgia

Ms. Laura Brewer
University of Georgia
Athens, GA

Great Plains

Dr. John Andrews
Dr. Nicole Colston
Oklahoma State University
Honors College
Stillwater, OK

Greater Washington, D.C.

Dr. Rebecca Kiriazes
Dr. Jason Davison
Catholic University of America
Washington, D.C.

Hawaii and Pacific

Dr. Courtney Chang
Hawaii Academy of Science
Honolulu, HI

Heartland

Mr. Mike Keller-Wilson
Mr. Brian Douglas
The University of Iowa
Iowa City, IA

Illinois

Dr. Amanda Weidhuner
Ms. Angela Henson
Southern Illinois University
Carbondale, IL

Indiana

Dr. Kenneth Reid
Dr. Leah Courtland
University of Indianapolis
Indianapolis, IN

Intermountain

Ms. Deborah Taylor Ivie
Ms. Meggan Callister
Utah State University Extension
Logan, UT

Kentucky

Dr. Terri L. Tinnell
University of Louisville
Louisville, KY

Louisiana

Mr. Chris Campbell
Mrs. Diane Madden
Louisiana Tech University
Ruston, LA

Maryland

Ms. Bonnie M. Green
Ms. Michelle Reloba
The Patuxent Partnership
Lexington Park, MD

Michigan

Dr. Sandra Yarema
Dr. Marion Tate
College of Education, Wayne
State University
Detroit, MI

Mississippi

Dr. Kendrick Buford
Dr. Allison Downing
The University of Southern
Mississippi
Hattiesburg, MS



Missouri

Dr. Roger Fales
Mrs. Kate Reuter
University of Missouri
Columbia, MO

New England Northern

Mr. Cary James
University of Maine
Orono, ME

New England Southern

Dr. Jennifer Pearce
Dr. Adria Updike
Roger Williams University
Bristol, RI

New Jersey Northern

Ms. Tamiah Brevard-Rodriguez
Ms. Candice Haigler
Rutgers, The State University of
New Jersey
New Brunswick, NJ

New Jersey Southern

Dr. Mary-Ellen Rada
Ocean County College
Toms River, NJ

New York-Long Island

Dr. Panayiotis Meleties
Ms. Dawn Hewitt
York College of the City
University of New York
Jamaica Queens, NY

New York-Metro

Dr. Panayiotis Meleties
Ms. Dawn Hewitt
York College of the City
University of New York
Jamaica Queens, NY

New York-Upstate

Ms. Donna Burnette
Ms. Kierra McInnis
Rochester Institute of
Technology
Rochester, NY

North Carolina

Ms. Alisa Wickliff
The University of North Carolina
Charlotte
Charlotte, NC

North Central

Dr. Sally Mallowa
Dr. Katelyn Hurley
Augustana University
Sioux Falls, SD

Ohio

Dr. Carmen S. Dixon
Capital University
Columbus, OH

Oregon

Dr. Kendrick Buford
The University of Southern
Mississippi
Hattiesburg, MS

Pennsylvania

Dr. David B. Klindienst
Ms. Kelsi Newman
Mr. James Patrick Myers
Juniata College
Huntingdon, PA

Philadelphia and Delaware

Dr. Susan Jansen Varnum
Ms. Tiffany ElBardissi
Temple University College of
Science and Technology
Philadelphia, PA

Puerto Rico

Dr. Julio de Jesús
Intellexi Foundation
Gurabo, Puerto Rico

South Carolina

Dr. Yanwen Wu
University of South Carolina
Columbia, SC

Southwest

Dr. Kendrick Buford
The University of Southern
Mississippi
Hattiesburg, MS

Tennessee

Mrs. Trixie Cooper
Ms. Gabbi Martin
University of Tennessee
Knoxville, TN

Texas

Ms. Rhiannon Kliesing
Texas A&M University College
of Arts and Sciences
College Station, TX

Virginia

Dr. Andrew Yeagley
Dr. Larry Collins
Longwood University
Farmville, VA

Virtual

Dr. Kendrick Buford
The University of Southern
Mississippi
Hattiesburg, MS

Washington

Dr. Kendrick Buford
The University of Southern
Mississippi
Hattiesburg, MS

West Virginia

Dr. Ed Wovchko
Dr. Tracey DeLaney
West Virginia Wesleyan College
Buckhannon, WV

**Wisconsin/Upper Peninsula
Michigan**

Mrs. Sheila Simonsen
Carthage College
Kenosha, WI

Wyoming and Colorado

Dr. Jonathan Prather
University of Wyoming
Laramie, WY



Section II

Student Participants

63rd National Junior Science and Humanities Symposium

Alabama

Ashu Anand
Aanchal Behara
Monisha Bommu
Rania Masri
Prisha Sharma

Alaska

Lily Anderson
Ruby Tansy
Thomas Tilbury
Julia Wang
Priscilla Wang

Arizona

Eniah Endriga
Karylle Garcia
Shubham Kale
Iraj Shroff
Aditya Tyagi

Arkansas

Aakash Bhattacharyya
Bennett Chen
Mithun Nelluru
Lillian Ouyang
Siddharth Sridharan

California Northern

Roshan Amurthur
Andrew Liang
Paarth Nawani
Ahvish Roy
Joshua Wu

California Southern

Chloe Chen
Nathan Kang
Aiden Kwon
Tanya Mandyam

Chicago

Elora Cianciolo
Abby Falkoff
Niyathi Girish
Catherine Ji
Amiritha Praveen

Connecticut

Jingyan Liu
Tyler Malkin
Rithvik Suren
Cooper Taylor
Lula Wang

DoDEA Europe

Jessie Brenay II
Raegan Cayce
Alexandra Quintanilla
Nicholas Vail
Trent Wilkerson

DoDEA Pacific

Miyeong Berran
Callie Green
Chloe Lee
Lan Legros
Sakura Lopez

Florida

Tanishka Aglave
Victoria Krupica
Akshay Kumar
Suvir Leekha
Alynza McBride

Georgia

Michelle Diep
Pragathi Kasani-Akula
Max Lee
Cain Patel
Anushka Sable

Great Plains

Elizabeth Barnes
Sahira Bhakta
Lawrence Dao
Cooper Frerichs
Raymond Jiang

Greater Washington, D.C.

Anusha Agarwal
Madeline Levorson
Oliver Wang

Hawaii and Pacific

Amelie Chen
Justice Kong
Travis Osaki
Lelani Phan
Kian Sanchez

Heartland

Erin Chen
James Peng
Caleb Rowe
Noah Shin
Henry Zou

Illinois

Sidharth Brahmandam
Meher Garg
Avirag Hosakote
Marcus King
Sohum Mehta

Indiana

Norah Ahmed
Sean Borneman
Valerie Fu
Ankur Kapileshwar
Brianna Marable



Intermountain

Jordan Chong
Kinzey Clark
Maxime Diaz
Ian Jake Kim
Shaelyn Tolleson Knee

Kentucky

Annika Chada
Chaturya Paladugu
Aniket Tadinada
Wanda Wu
Ella Xing

Louisiana

Elaine Lu
Vennela Malireddy
Claire McGuinness
Aashni Shah
Maya Trutschl

Maryland

Nadiat Adedoyin
Kelly Ji
Diya Kamalabharathy
Mia Sproge
Dhruv Veda

Michigan

Paul Garrison
Maya Hammond
Michael Hua
Diya Ramakrishnan

Mississippi

Jaden Claire Everett
Jun Jang
Yoon Jang
Ananya Mantri
Harrison Shao

Missouri

Zebediah Bruna
Vihaan Choudhary
Natalie Kiehl
Varsha Manikandan
Satvik Rachagani

New England Northern

Eric Buehler
Ethan Liu
Sofie Rueter
Dan Stoicov
Saladin Wise

New England Southern

Yifan Ding
Lucas Jiang
Ethan Yan
Lucy Zhang
Ethan Zhou

New Jersey Northern

Neel Ahuja
Danial Han
Kevin Jin
Ari Kestenbaum
Paridhi Tyagi

New Jersey Southern

Zachary Ciappa
Maggie Kelleher
Vinil Polepalli
Zoey Smith
Morgan Zylinski

New York-Long Island

Natalie Osorio
Sean Skinner
Emma Eu
Emma Wen
Henry Zhang

New York-Metro

Julia Hettleman
Sidney Lin
Soleil Wizman
Vanessa Wu

New York-Upstate

Shrey Kumar
Sebastian Lashmet
Nora Morton
Riya Raina
Aaron Weinberg

North Carolina

Jamie Cheng
Luca Cyrus
Ronit Dey
Noga Gercsak
Anna Tringale

North Central

Quinn Hughes
Shefali Meagher
Selena Qiao
Alexandra Sigmond
Riddhi Singhvi

Ohio

Nikhil Bhimireddy
Rebecca Jacob
Anshul Sharma
Nandita Srikumar
Elaine Theodorou

Oregon

Arjun Agarwal
Andrew Ma
Akash Ragam
Kavin Ramadoss
Ashvika Singhal

Pennsylvania

Veda Gandhi
David Markwood
Alexandra Meier
Sritej Padamanabhan



Philadelphia and Delaware

Rishi Amaravadi
Weiham Chen
Matthew Lo
Niranjana Sendil Kumar
Angela Wang

Puerto Rico

Gianna Rios Garcia
Daniela Mendez Cora
Paula Mendez Torres
Lorena Pachiaridi
Sriniketan Sridar

South Carolina

Sadhana Anchoori
Ma Berg
Srianeesh Kalva
Morgan Kay
Yiqing Ye

Southwest

Sofia Peinado
Sarah Perales
Dayra Realzola
Anderson Stoker
Aarush Tutiki

Tennessee

Brandon Bonamarte
Kimberley Huang
Langalibalele Lunga
Rohan Ramachandran
Lin Zheng

Texas

Chloe Lee
Sanskriti Manoharan
Sativika Nadela
Siri Peddenti
Diya Shah

Virginia

Ridhi Gutta
Avani Kaur
Bhoomika Kaur
Kevin Zhang

Virtual

Saanvi Chakraborty
Lillian Costen
Hailey Kim
Aiden ko
Ankit Walishetti

Washington

Lakshmi Agrawal
Navneeth Badhri
Hamsini Ramanathan
Aditya Sengupta
Zain Shariff

West Virginia

Maya Panta
Manvitha Sanjaya
Pavan Subramani
Iqraa Zaman

**Wisconsin/Upper Peninsula
Michigan**

Ali Abidi
Anand George
Riya Kalluvila
Hannah Lee
Meenakshi Pradeep

Wyoming and Colorado

Naomi Kruse
Padmalakshmi Ramesh
Aanshi Shah
Om Vegesna
Amy Xia



Section III

Abstracts of Student Papers

Alabama

Developing Emulsion Additives to Optimize Rheological Behavior in Non-Aqueous Magnetorheological Smart Fluids

Ashu Anand

Alabama School of Fine Arts, Birmingham, AL

Mentor: Dr. Amanda Koh, University of Alabama

Magnetorheological fluids (MRFs) are smart materials capable of rapid, controllable viscosity shifts when subject to magnetic fields. MRFs transition from a liquid to a semi-solid phase as ferromagnetic particles suspended within the carrier fluid align into chain-like structures when magnetized. Tunable viscosity performance enables MRF application in adaptable energy-damping systems, including rehabilitation prosthetics and seismic dampers. Current research at the Koh Laboratory at the University of Alabama demonstrates enhanced viscosity modulation in aqueous MRF systems when integrated with emulsions, leading to the development of novel magnetorheological emulsions (MREms). However, aqueous systems present significant challenges from instability and reduced durability in rust-prone metals. This study aimed to (1) design a stable, non-aqueous emulsion system to formulate non-aqueous MREms and (2) compare the performance of developed MREms to traditional MRFs. A successful emulsion was formulated using silicone-based polydimethylsiloxane emulsified in glycerol and stabilized with fumed silica serving as a Pickering emulsifier. The manipulation of key characteristics—iron concentration, droplet size, magnetized soak time, and magnetic flux—revealed that MREms exhibit enhanced viscosity transformations under specific stress. Notably, MREms subjected to extended magnetized soak time and increased magnetic flux outperformed traditional MRF viscosity behavior. Findings from this study demonstrate that non-aqueous MREms can achieve superior performance, offering a more robust alternative to both aqueous MREms and non-aqueous MRFs for improved damping. Future research should refine MREm formulations and drive scalability, unlocking potential for high-impact industrial applications in automotive suspension systems, seismic mitigation, and vibration-damping technology.

Exploring *TFE3* Overexpression as a Novel Strategy to Promote Lysosomal Biogenesis and Enhance Cellular Resilience in Vulnerable Neuronal Populations

Aanchal Behara

Alabama School of Fine Arts, Birmingham, AL

Mentor: Dr. Rita M. Cowell, University of Alabama at Birmingham

Frontotemporal dementia (FTD) and amyotrophic lateral sclerosis (ALS) are fatal neurodegenerative disorders characterized by progressive neuronal loss and pathological mislocalization of TDP-43, an RNA-binding protein essential for cellular homeostasis. Impaired lysosomal degradation contributes to disease progression by disrupting protein clearance, leading to toxic accumulation of misfolded proteins and cellular dysfunction. The MiT/TFE transcription factor family, including *TFE3*, regulates lysosomal biogenesis and autophagy, making it a promising target for therapeutic intervention. However, the precise role of *TFE3* in neuronal lysosomal function remains poorly understood.



This study investigated whether *TFE3* overexpression enhances lysosomal biogenesis, whether forced nuclear localization alters lysosomal function, and whether nuclear mislocalization induces cellular stress. Using stereotaxic AAV-mediated delivery, FLAG-*TFE3* was overexpressed in the mouse hippocampus, while a tamoxifen-inducible FLAG-*TFE3*-ERT construct enabled controlled nuclear translocation. Immunofluorescence and quantitative image analysis were performed to assess lysosomal activity (cathepsin D, CTSD) and DNA damage (γ H2AX).

TFE3 overexpression significantly increased CTSD expression, confirming enhanced lysosomal biogenesis. However, forced nuclear localization did not elevate overall CTSD levels but altered its subcellular distribution, forming punctate structures indicative of impaired lysosomal trafficking. Additionally, *TFE3*-ERT expression markedly increased γ H2AX levels, signaling elevated DNA damage and cellular stress.

These findings suggest that while cytoplasmic *TFE3* promotes lysosomal function and biogenesis, its nuclear mislocalization induces toxicity. Future studies should elucidate the mechanisms regulating *TFE3* trafficking to harness its lysosomal benefits while minimizing nuclear stress. Understanding these pathways may provide novel therapeutic strategies to enhance TDP-43 clearance and mitigate neurodegeneration in FTD/ALS.

Using DeePMD to Predict the Relaxed MoTe₂ Moiré Structure

Monisha Bommu

Alabama School of Fine Arts, Birmingham, AL

The modeling of MoTe₂ bilayers is essential for applications in two-dimensional materials science. Molybdenum ditelluride (MoTe₂) is a layered transition metal dichalcogenide (TMD) with remarkable electronic and structural properties, making it desirable for next-generation electronic, optoelectronic, and spintronic devices. When stacked as bilayers, MoTe₂ exhibits intriguing electronic behaviors, which depend critically on the stacking order, interlayer interactions, and strain effects. Density Functional Theory (DFT) is the primary model used to predict the electronic structure of MoTe₂ bilayers, showing detailed predictions of how atomic configurations influence electronic band structures, charge distribution, and interlayer coupling. However, DFT's high computational cost is a challenge for large-scale simulations. By training AI models on DFT-generated data for MoTe₂ bilayers, we can significantly accelerate these simulations while preserving sufficient accuracy, allowing for a deeper exploration of their electronic properties and functional potential. This research investigates bilayer MoTe₂ systems by examining the atomic displacements and interlayer forces under relaxation. A dataset made up of 144 bilayer configurations was analyzed, each with varying atomic shifts and stacking arrangements. Using DFT simulations, relaxed atomic structures were extracted, providing energy and force data critical for understanding stability and deformation behavior. A machine learning model based on the DeePMD framework uses atomic coordinate to predict interatomic interactions like force and energy with high accuracy, enabling computationally efficient exploration of the material's potential energy surface. The DeePMD model was able to predict the energy of a MoTe₂ system with an error of 0.000241 and force with an error of 0.000786.



Investigating the Antibacterial Properties of *Moringa Oleifera* Against *Escherichia Coli* and *Bacillus Cereus*

Rania Masri and Denise Otali

Alabama School of Fine Arts, Birmingham, AL

Teacher: Ms. Hungsin Chin, Alabama School of Fine Arts

Moringa oleifera, known as a “miracle tree,” has been historically used as a worldly medical remedy. The objective of this investigation aimed to test whether different mediums of *Moringa Oleifera* prevent bacterial growth of *Escherichia coli* and *Bacillus cereus*. *E. coli* (gram-negative) has a thin peptidoglycan layer and an outer membrane, while *B. cereus* (gram-positive) has a thick peptidoglycan layer. This extra membrane difference makes gram-positive bacteria more susceptible to antibiotics. The three different mediums of *Moringa Oleifera* that were tested consisted of a store-bought extract, a self-prepared paste, and crushed leaves from a homegrown plant. It was hypothesized that the extract would have the strongest effect compared to the other two treatments due to the extract's high concentration. The various scientific treatments and control variables were tested on *E. coli* and *B. cereus* in petri dishes that contained nutrient agar. After incubating the petri dishes for 24 hours at their respective temperatures, bacterial inhibition was determined by measuring zones of inhibition which are areas around a sterile disc where bacteria ceases to grow. After an ANOVA Single-Factor Test revealed a p-critical value under 0.05, the null hypothesis was rejected. A Tukey Test revealed that the positive control inhibited a significant amount of both *E. coli* and *B. cereus*, but *Moringa Oleifera* leaves only prevented a significant amount of *B. cereus*. These results show that *Moringa Oleifera* leaves prevent bacterial growth and could be used as a bacterial inhibitor in the future.

Impact of Environmental Cadmium Exposure on Efferocytosis in Alveolar Macrophages

Prisha Sharma

Alabama School of Fine Arts, Birmingham, AL

Mentor: Dr. Ranu Surolia, University of Alabama at Birmingham

Background: Cadmium (Cd) is a toxic heavy metal found in cigarette smoke, fossil fuel emissions, and industrial coal-powered smoke. Exposure to cadmium poses severe health risks, including emphysema, asthma, and lung cancer. While industrialized cities like Birmingham, Alabama, face significant exposure, the impact is global, affecting highly polluted areas such as New Delhi, India, and Lahore, Pakistan. This study examines the effects of environmental cadmium exposure on efferocytosis in alveolar macrophages—phagocytic cells responsible for clearing apoptotic cells in the lungs. Efferocytosis is mediated by the scavenger receptor MerTK, which binds to phosphatidylserine on apoptotic cells. Objective: This study aims to determine whether cadmium exposure disrupts MerTK function and impairs the efferocytic ability of alveolar macrophages. Methods: Both in vitro and in vivo approaches were used. In vitro, mouse alveolar macrophages (MH-S cell line) were cultured and treated with cadmium, followed by efferocytosis assays and flow cytometry to assess efferocytic function. Immunostaining and Western blotting were performed to detect MerTK cleavage. In vivo, histological analysis of cadmium-induced peribronchial fibrosis in mouse lung tissue and immunohistochemistry (IHC) imaging were conducted to evaluate cell death. Results: Cadmium exposure significantly impairs efferocytosis in alveolar macrophages by increasing MerTK cleavage. Higher cadmium concentrations correlate with reduced efferocytic activity, increased lung inflammation, fibrosis, and acute lung injury. Conclusion: Cadmium exposure decreases efferocytosis efficiency by promoting MerTK cleavage. Future research will investigate the molecular mechanisms underlying cadmium-induced MerTK cleavage, the role of reactive oxygen species (ROS), and cadmium's broader impact on efferocytosis-related receptors and signaling pathways worldwide.



Alaska

The Impact of Water - Induced Finger Wrinkles on Object Manipulation

Lily Anderson

B.E.S.T. Homeschool, Fairbanks, AK

Mentor: Daisy Huang, College of Engineering and Mines, University of Alaska Fairbanks

This study investigates whether the active nerve reflex that causes finger wrinkling upon water exposure enhances the ability to manipulate wet objects. Finger wrinkling, caused by vasoconstriction in the fingertips, has been suggested to provide an adaptive advantage by improving grip in wet conditions. However, previous studies using only small, rigid objects like marbles have yielded mixed results. This research expands on prior work by incorporating larger and deformable objects to better represent organic materials that early humans may have handled in wet environments. This research expands on prior work by incorporating larger and deformable objects to better represent materials that early humans may have encountered in wet environments. Using a within-subjects design, fourteen participants completed timed object manipulation tasks involving small and large marbles, grapefruit, water balloons, and Orbeez under two conditions: wrinkled and non-wrinkled fingers. Objects were transferred between water-filled containers through a 10 cm diameter hole in a plexiglass screen. We also measured the coefficient of friction between the fingers and hard or squishy surfaces using a custom-built tribometer. On average, participants performed better with wrinkled fingers across all objects, but only the Orbeez trials showed a statistically significant improvement of 20%, with average times decreasing from 53 to 42 seconds. Tribometer tests revealed a 14% increase in friction in the wrinkled condition when interacting with squishy surfaces, but no meaningful difference with hard surfaces. These results support our hypothesis that finger wrinkling may offer an evolutionary advantage for gripping pliable, wet objects rather than rigid ones.

Different Factors That Affect Choices in the Game of Rock-Paper-Scissors

Ruby Tansy

Lathrop High School, Fairbanks, AK

Teacher: Christopher Benshoof

In this study, I will look into two aspects of the game of Rock-Paper-Scissors, including how age and sex affect the first move choice and the conditional responses of previous round results. Beginning this process, I looked at different papers studying the game to get an idea of what to expect and how to perform my research. I played 55 matches against people of various ages and genders to get a wide variety of people in my sample. I used an AI-coded website to help track the data from each round and saved it all to a spreadsheet to make graphs and tables to help display my results. My null hypothesis was that neither age or gender played a role in first move choice, and that there was no conditional response to winning, losing, or tying. Using chi-square tests I failed to reject the null hypothesis for age, and after winning or tying, however, I found a relationship between gender and first move and between losing a previous round and the type of next move (upgrade- switching to the move that would beat the previous one, downgrade - switching to the one that would lose to it, or none - keeping the same move). After finding the relationships, I was able to construct 95% confidence intervals for the most frequent choices in these scenarios: females choosing scissors first (0.3487, 0.6799), males choosing rock first (0.232, 0.668), and people upgrading after losing (0.4547, 0.6804).



You Shall Not Pass: How Hall Pass Usage Correlates with Student Success

Thomas Tilbury

Lathrop High School, Fairbanks AK

Teacher: Christopher Benshoof

The goal of this study was to determine how the usage of hall passes correlates with high school students' success, measured as a grade point average. Furthermore, it explored how that correlation differs between grade levels. I hypothesized that there would be a negative correlation between both hall pass frequency/duration and student GPA, and that upperclassmen students would demonstrate the strongest correlation. To explore these ideas, electronic hall pass data was collected from Lathrop High School in Fairbanks, Alaska, from a random sample of anonymous students of different grade levels. All of it being from just the first semester, the data included: total number of e hall passes, the sum of those pass durations, and the following students' first semester GPAs. This data could be biased, as it would likely underestimate the true frequency and duration of passes due to students who chose not to fill out the e pass. From this data, we concluded that for all students, the number of passes taken and GPA had a moderate negative correlation represented by an exponential function. For all students, pass duration and GPA have no significant correlation. Then, considering each individual class, (freshman, sophomore, junior, senior), there was the strongest and steepest negative correlation between pass frequency and GPA for freshmen.

Assessing fish label accuracy via DNA barcoding from a Fairbanks market

Julia Wang

Fairbanks BEST Homeschool, Fairbanks, AK

Mentor: Dr. Andrés López, Department of Fisheries, University of Alaska Fairbanks

With fish growing in popularity as a food, and global consumption of it likewise increasing, correct identification and accurate labels of fish products help to protect consumers, ward off potential fraud and possible overfishing and loss of resources. To that end, DNA barcoding is a method that has been demonstrated to provide precise and swift identification of fish species. In this paper, the labeling accuracy of a fish market in Fairbanks is assessed by collecting samples from ten fishes and applying the DNA barcoding method to verify their labels. It is shown that DNA barcoding had an 80% success rate for identification, and out of the samples identified, 25% of the samples were mislabeled. Though simply a limited case study, all these cases begin to show the prevalent issue of mislabeling, even in a small city like Fairbanks. The next step would be to expand the study to include several samples of each fish as well as samples from all the fish markets to gain a fuller picture of mislabeling issues in Fairbanks, Alaska.

Effects of Adenosine Outside the Brain in Hibernation for Arctic Ground Squirrels

Priscilla Wang

Fairbanks BEST Homeschool, Fairbanks, AK

Mentor: Dr. Kelly Drew, Department of Chemistry and Biochemistry, University of Alaska Fairbanks

Hibernation is an adaptation found in animals that, if it can be safely induced in humans, may help extend space missions and help the human brain recover from low oxygen situations. However, the physiological causes of hibernation are not well understood. One factor that plays a crucial role in hibernation is adenosine, a molecule that is found in the bloodstream and brain. In past studies, torpor was induced by exciting adenosine A1 receptors in the brain via a central administration of an adenosine agonist, while a central administration of an adenosine antagonist reverted torpor. It is unclear if these receptors play the same role outside of the brain. In this study



we conduct experiments on 5 Arctic Ground Squirrels to assess whether adenosine outside of the brain has any effect on hibernation. We habituated them to get used to the handling and injection of the drugs. Two drugs were injected into them, one with a molecule to block the adenosine's receptor (an adenosine antagonist) and another with sterile water. Three measurements, carbon dioxide (CO₂) production, heart rate (HR), and body temperature (T_b) were acquired for two hours after each drug treatment. From the data, we concluded that adenosine in the bloodstream did not have an effect on the hibernation of Arctic Ground Squirrels as the drug with 8-sulphophenyl theophylline (8-SPT), the adenosine antagonist, did not show any significant difference with sterile water. Our findings further highlight the role played by adenosine A1 receptors in the brain to regulate hibernation.

Arizona

Impact of Forest Fires Scars on the Spread of Noxious and Invasive Weeds in the Tonto National Forest: A Comprehensive Snapshot Ecosystem Stress Analysis

Eniah Endriga

Harvest Preparatory Academy, Yuma, AZ,

Teacher: Alfred S. Santos

Mentor: Dr. Ryan Nicholas

Over the past year, there were more than 61,000 wildfires in the US, which is about ninety percent above the 20-year average. Its resulting aftermath has given an opportunity for noxious and invasive weeds to flourish, posing a threat to the ecosystem. To address this problem, this study investigated the impact of forest fire scars on the spread of noxious and invasive weeds in the Tonto National Forest.

This project was conducted using the following methods: First, a 30ft x 30ft plot was established in each site using GPS coordinates, which was divided into four quadrants (15ft x 15ft) for even sampling. Second, all plant species were recorded, paying close attention to the invasive species, estimating their percentage cover, density, and spread. Third, soil samples were collected to analyze texture, moisture, and pH. Fourth, notes were taken on the visible impacts of fire, including erosion, soil loss, and vegetation damage for the Bush and Cactus Fire scars. Lastly, GIS, Correlation Analysis, Regression Analysis, and Spatial Analysis were conducted to analyze the data.

The results showed that red brome has a high risk (56.7%) of spreading, meaning it should be the highest priority for some kind of control. While stinknet and buffelgrass has moderate risk which might require more targeted management approaches. This demonstrates that when a plant is invasive, there's a 63.3% chance that these plants will successfully move to new areas. This research presents a further elaboration regarding the relation forest fires scars in the spread of invasive weeds.



Understanding the effect of Agricultural Practices on Valley Fever through a Dual-Model Approach using Environmental Factors

Shubham Kale

Paradise Valley High School, Phoenix, AZ

Teacher: Michelle Landreville

Valley Fever (VF), or coccidioidomycosis, is a fungal infection influenced by environmental factors such as dust exposure. This project investigates the impact of different agricultural practices (APs) on VF epidemiology through a dual-model computational approach. By merging environmental and VF case data from Maricopa County, Arizona, this study employs a Gradient Boosting Regressor (GBR) and a Multilayer Perceptron (MLP) to predict VF case trends and assess the effectiveness of various APs in reducing disease incidence. The research framework consists of four key stages: (1) data collection and preprocessing of environmental factors such as PM2 emissions, temperature, precipitation, and sunlight, (2) model development and calibration using GBR and MLP to capture both steady trends and extreme fluctuations, (3) experimental validation using an Arduino-based sensor system to measure the effects of APs, and (4) comparative analysis of predicted versus actual VF case reductions. The model achieved a R^2 score of 0.903, explaining 90.03% of VF case variance, with a mean absolute error (MAE) of 97.197 cases. The results indicate that mulch is the most effective AP, reducing VF cases by 21.32%, compared to 15.39% with organic material cover. Future research will focus on expanding datasets from CDC, NOAA, and NASA, integrating population density metrics, testing alternative models like LSTM and XGBoost, and evaluating additional APs such as salt brine treatments to increase predictive accuracy and real-world applicability.

Year 2 Study- EcoPatch: Innovative Biodegradable Band-aids to Assess the Efficacy of Quercetin and Amoxicillin in Wound Care Application

Karylle Macy Garcia Operania

Harvest Preparatory Academy, Yuma, AZ

Teacher: Alfred S. Santos

Mentor: Derek Reichel

Band-aids are used to speed up the healing process and protect wounds from germs. Certain studies have revealed that commercial bandages may not be as efficient as what is advertised. Annually, over 200 million units of bandages are sold in the United States alone. Because of this, countless bandages are being discarded, leading to significant increases in landfill waste. To address this problem, this study investigated a possible alternative to commercial band-aids using Quercetin and Amoxicillin.

This experiment was accomplished using the following methods: First, to prepare the concentrations, I designed 15 formulations from A-O with varying concentrations. Secondly, I heated the materials using a hot plate and magnetic stirrer to encapsulate the formulation. Thirdly, the Kirby-Bauer Assay was conducted to test their antimicrobial effects. Band-aid A with no concentration was used as a control. To create the biodegradable band-aid, 1 gram of agar-agar, sodium alginate and carboxymethyl cellulose, were mixed and heated in 100ml distilled water, vinegar and glycerin. Heated solutions were placed in a mold and let to rest at room temperature. Lastly, antimicrobial assays (Kirby-Bauer and Area Coverage Analysis) were conducted. All the data was analyzed using Bliss Synergy, Chuo Talalay, and Microsoft excel.

The results showed that the formulation with higher concentrations has higher zones of inhibition. This was supported by the calculated p-values of less than 0.05. Among all the formulations, J



and K showed effectiveness when combined. The biodegradable band-aid infused with Quercetin and Amoxicillin demonstrated great antimicrobial effects against E. coli.

Natural Aqua Purifier: A Novel and Sustainable Water Purification Approach Utilizing Natural Coagulants for Easy Implementation in Rural Regions

Iraj Shroff

BASIS Chandler, Chandler, AZ

Teacher: Alex Harmatuck

Access to clean water is one of our most basic human needs. In fact, unsafe water sources are responsible for over 1 million deaths annually. UN Sustainable Development Goal 6.1 targets “universal and equitable access to safe, affordable drinking water for all” by 2030. Current water purification methods for rural areas have hazardous effects on human health, are expensive, and are not readily available. As a result, it was hypothesized that a combination of natural coagulants would purify water effectively.

This study investigated the results of combining the natural coagulants moringa seed powder(M), neem leaf powder(N), and peanut husk powder(P) to purify raw water with heavy metal contamination. Water purification tests were conducted at home using minimal equipment to simulate the environment in rural regions. Furthermore, jar tests were performed in the lab to validate the accuracy of the results. The solution used the processes of coagulation, flocculation and sedimentation to purify the water. The proteins in the natural coagulants contain positive charges which neutralize the colloids' negative charges, creating “flocs” that sink to the bottom. Filtration was used to remove the flocs. Experimental findings proved the hypothesis, M+P successfully reduced heavy metal concentrations: lead concentration by 94.5%, zinc by 79.4%, copper by 19.8%, and manganese by 52.4%.

This research paves the way for providing clean water to the 2.2 billion globally who lack access to it by developing a novel, sustainable, and inexpensive water purification mixture for rural regions.

The Emotional Resonance of Music: Exploring the Interplay of Frequency, Empathy, and Therapeutic Effects

Aditya Tyagi

Chaparral High School, Scottsdale, AZ

Music is often referred to as the “universal language” because it has the power to connect people from diverse backgrounds, identities, and cultures. It transcends barriers, enabling individuals to appreciate and understand each other through shared musical experiences. As British ethnomusicologist John Blacking defines it, music is “humanly organized sound,” suggesting that its definition can be personalized. The connection between music and people lies in its ability to evoke emotions. Emotions, considered as “energy in motion,” are complex reactions involving experimental, behavioral, and psychological components (UWA Psychology and Counseling News, 2019). Understanding how thoughts and emotions interplay is crucial before exploring how music influences the brain, as emotions relate to energy and frequencies. Humans can be viewed as electromagnetic beings because our bodies continuously emit light, energy, or frequencies that convey specific messages or intentions. As discussed in *Becoming Supernatural*, “When we think a thought, those networks of neurons that fire in our brain create electrical charges. When those thoughts also cause a chemical reaction that results in a feeling or an emotion, those feelings generate magnetic energy. This energy merges with the electrical charges from thoughts to produce an electromagnetic field reflecting your state of being.” This means that our feelings



create magnetic fields that attract similar frequencies. For example, listening to sad music can have surprising effects. Research by Kawakami and colleagues (2013) found that listening to sad music often increases positive emotions such as tranquility and serenity while reducing negative emotions like anxiety and anger.

Arkansas

Early Detection of Critical *Salmonella* Cases for Pre-Emptive Treatment via Novel Biomarkers discovered through Protein Domain Analysis and Machine Learning

Aakash Bhattacharyya

Central High School, Little Rock, AR

Teacher: Ms. Lee Conrad, Mr. Patrick Foley, and Dr. Beth Maris. Central High School

Mentor: Dr. David Ussery, Professor, Department of Biomedical Informatics, UAMS

Salmonella is a common pathogen, infecting more than a hundred million people yearly. About 8% of these cases worldwide, result in life-threatening conditions. The case fatality ratios of these critical conditions can be as high as 30%, however with earlier treatment can be reduced to lower than 1%. Thus, rapid assessment of clinical case severity is essential for improving patient outcomes and optimizing healthcare resources. Advancements in genome sequencing technologies have enabled the analysis of bacterial genomes from many clinical cases, opening new opportunities for precise and timely diagnosis. This study proposes a genome-based framework for identifying critical *Salmonella* cases before the onset of critical symptoms and facilitating early medical intervention. By leveraging the novel approach of Protein Family (Pfam) Domains as the representation for genomic data, the complex genetic profiles of *Salmonella* cases are simplified into interpretable features. The severity levels of cases were investigated through rigorous data analysis, resulting in a set of 70 novel PFAM biomarkers for severity. Machine Learning was employed to assess the predictive power of the curated Pfam biomarkers, achieving high accuracy (~93%) in identifying the severity levels of cases. The results demonstrate the efficacy of the proposed approach and biomarkers. This framework highlights the potential of using bacterial genomic data in clinical decision-making, opening the window for timely personalized interventions for *Salmonella* infection management.

Forecasting the Future: A Predictive Modeling Approach to Deciphering Climate Change's Impact on US-Grown Soybeans and Estimating County-Level Crop Yields

Bennet Chen

Little Rock Central High School, Little Rock, AR

Teacher: Mrs. Lee Conrad, Little Rock Central High School

Understanding climate change's impact on soybeans, a versatile crop, through the use of yield modeling is critical for future food insecurity issues. This study aimed to determine if various climate change factors contributed to soybean yields, hypothesizing their importance to the calculation of yields, and to create a predictive model to forecast county-level yields. This study separated NOAA weather and USDA fertilizer data from various soybean-yielding counties into 7 variable categories and grouped those variables into high, midrange, and low-yield scenarios to compare against each other through ANOVA tests. The statistically significant variables (p -value <0.05), including all temperature and fertilizer variables, were constructed into a multiple linear regression analysis comparing against ~50-year historical county-level NASS soybean yields. Then, a new model was created with the variables that contributed statistically significantly to the yield's variance, which included days over 32.22 degrees Celsius, potash usage, and phosphate usage, along with the past year's yields. This model yielded an R-squared value of



0.651, with a correlation of 0.782 against actual yields on a testing set, when predicting county-level yields, and 0.946 for yearly overall yields. Using the model, an easy-to-use website was created for instant soybean yield predictions. With this, the government and farmers can cheaply predict crop yields for better preparation. Overall, with rising temperatures from climate change, this study highlighted through the use of predictive models how an increasing number of days greater than 32.22 degrees Celcius will be detrimental to soybean yields.

Interactions of Kidney Function Related Genes and Proteins with Anticancer Drugs and Strategies to Mitigate their Adverse Effects

Mithun Reddy Nelluru

Little Rock Central High School, Little Rock, AR

Teachers: Mr. Patrick Foley and Mrs. Lee Conrad, Little Rock Central High School

Mentors: Dr. John D. Imig and Dr. Abhishek Mishra, Department of Pharmaceutical Sciences, University of Arkansas for Medical Sciences

Sorafenib, an antiangiogenic multikinase inhibitor (MKI) used in the treatment of renal carcinoma has been linked to the development of focal segmental glomerulosclerosis (FSGS) due to inhibition of proliferation related signaling via the vascular endothelial growth factor receptors (VEGFRs) (Wen et al., 2018). Sorafenib's nephrotoxic properties also lead to dysregulation of differential gene expressions leading to the upregulation or inhibition of vital kidney survival related pathways. Epoxyeicosatrienoic acids (EETs), are a group of endogenous fatty acids that have protective properties including pro-angiogenesis, counteracting sorafenib-induced renal dysfunction (Imig, 2015). This study aims to study pathways responsible for sorafenib-induced FSGS progression and seeks to explore preventative strategies using the protective drug 8, 9 EET analog. It was hypothesized that vital kidney function related genes are responsible for the development of FSGS, and 8, 9 EET analog has protective properties that can counteract damaging pathways. Using the Nephroseq database, significantly dysregulated genes were obtained and screened via hierarchical clustering. Data was then uploaded to the QIAGEN IPA application, in which an ingenuity pathway analysis was conducted revealing key pathways responsible for FSGS development. These findings were further validated through in vitro experiments and genomic studies. This research revealed that sorafenib-induced FSGS is driven by an increase in inflammatory and oxidative stress pathways, resulting in further progression of fibrosis in the glomerulus. Genomic studies supported 8, 9 EET analog's protective properties, and its ability to regulate differential gene expressions, allowing it to counteract effects of sorafenib on oxidative stress and inflammation related pathways.

Physical Activity During Pregnancy and Cortical Gray Matter Development in Children: A Neuroimaging Study

Lilian Ouyang

Little Rock Central High School, Little Rock AR

Mentor: Xiaoxu Na

Many factors during pregnancy can potentially impact *in utero* brain development and have long-term consequences. To identify modifiable factors during pregnancy that can promote early brain development and long-term outcomes is very important. Physical activity during pregnancy is safe and may benefit the health of both the pregnant women and their offspring. However, it is unknown whether it will also impact offspring brain which develops rapidly during the gestation period. This research project aims to study the relationships between mother's physical activity level throughout pregnancy and child's cortical gray matter development measured by magnetic resonance imaging (MRI) and neurodevelopmental outcomes measured by the Behavior Rating Inventory of Executive Function (BRIEF) at age 8 years. The hypothesis is that higher physical



activity levels in the mothers is associated with better cortical development and neurodevelopmental outcomes in the children. High-resolution brain MRI datasets were post-processed using advanced methods and statistics tests were performed to study the relationships between physical activity parameters and cortical measurements as well as BRIEF scores. Eight regions in the left-brain hemisphere and four regions in the right brain hemisphere showed significant positive correlations in cortical gray matter volume or surface area with mother's physical activity during pregnancy. There were also significant correlations between physical activity parameters and BRIEF scores, indicating that the more physical activity throughout the mother's pregnancy, the less executive functions and neurobehavior issues in children. These novel results suggest that mother's physical activity during pregnancy benefits offspring's cortical gray matter development and neurodevelopmental outcomes.

The Neurobiology of Voluntary Exercise: A Novel Approach to Alleviate Chemobrain by Promoting Hippocampal Neurogenesis

Siddharth Sridharan

Little Rock Central High School, Little Rock, AR

Teacher: Ms. Lee Conrad, Little Rock Central High School

Mentor: Dr. Antiño R. Allen, PhD, Department of Pharmaceutical Sciences, University of Arkansas for Medical Sciences

Despite the improved and updated treatments available currently, breast cancer is the most prominent type of cancer among women worldwide. The common systemic chemotherapy, AC-T (Adriamycin, Cyclophosphamide and Paclitaxel) in a dose dense regimen, causes toxic side effects to the nervous system, which includes chemobrain. Studies have indicated that exercise may reduce inflammation, influence gut-brain axis and alleviate long-term cognitive side effects. This study was aimed to decipher the ability of voluntary exercise to alleviate chemotherapy-induced chemobrain in female mice.

C57/BL6 female mice were single housed with or without a running wheel and were subjected to Adriamycin (2 mg/Kg BW) + Cyclophosphamide (50 mg/kg BW) once weekly for 4 weeks, followed Paclitaxel (5 mg/kg BW) once weekly for 4 weeks. Behavior study in animals, and protein expression of neurogenesis and synaptic plasticity markers, microglial and astrocytes viability, and inflammatory markers were done in hippocampus tissue. Proteomics and microbiome analysis were done in hippocampus tissue, and fecal samples respectively.

AC-T induced neuroinflammation, impaired neurogenesis, and cognitive dysfunction. Behavior studies revealed that voluntary exercise was able to significantly alleviate the deficit in spatial memory. Voluntary exercise enhanced synaptic plasticity, modulated microglial and astrocyte viability, decreased neuroinflammation, promoted neurogenesis in the hippocampus and preserved essential microbiota of the gut-brain axis, which might have contributed to the prevention of long-term cognitive deficit after chemotherapy.

In conclusion, this study has provided evidence that voluntary exercise promotes hippocampal neurogenesis and may be useful as a potent adjuvant strategy to ameliorate chemobrain in breast cancer patients.



California Northern

NeoRhythm: A Neurocardiac Electrophysiology Based Explainable EEG and ECG System for Detection of Neonatal Seizures

Roshan Amurthur

The Harker School, San Jose, CA

Neonatal seizures go frequently undetected since an estimated 85% lack obvious clinical signs. This poses significant risk of severe neurological damage or mortality if not promptly diagnosed and treated. Existing technologies are complex and rely on expert interpretation, which is costly and inconsistent. Current neonatal seizure detection algorithms lack basis in seizure physiology, rendering them opaque to Neonatal Intensive Care Unit (NICU) physicians. This undermines clinician confidence and limits adoption in clinical practice. NeoRhythm, a novel seizure detection system is proposed. It is the first AI-driven system to integrate electrocardiogram (ECG) data with electroencephalographic (EEG) signals via a multimodal fusion deep-learning (DL) architecture. We hypothesize that integrating physiologically based multi-modal data within an explainable deep-learning framework yields enhanced seizure detection accuracy and transparent clinical insights. We employed four-step engineering methodology that begins with robust data preprocessing (filtering, segmentation, artifact removal), proceeds to deep-learning model training to address class imbalance, integrates explainable AI (XAI) to provide clinically interpretable justifications, and concludes with clinical protocol that centralizes signal acquisition and interpretability. Experimental results demonstrate that incorporation of ECG into EEG-based detection algorithms improves performance across benchmark models. Fusion architecture yields 94.9% sensitivity and 94.2% specificity, outperforming the current standard of care. Explainability features provide clinicians with transparent insights into physiology-based decision-making, building trust. Neurocardiac correlates provide confirmatory markers of seizure, augmenting deep-learning based models. NeoRhythm builds on existing vital-sign monitors and may assist resource-limited NICUs that lack on-site neurologists. NeoRhythm has the potential to improve neurological outcomes for newborns globally.

An Intelligent Bee Health Assessment System Using Cross-Attention-based Multimodal Neural Network for Visual and Audio Signals

Andrew Liang

The Harker School, San Jose, CA

Teacher: Ms. Anuradha Datar, The Harker School

Honeybees are crucial for pollinating approximately one-third of the world's food supply. However, honeybee colonies have declined by nearly 40% over the past decade due to threats such as parasites. Traditional beehive monitoring, including manual inspections, is often subjective, disruptive, and time-consuming. Machine learning models have been used to improve beehive health assessments. However, previous studies have primarily relied on single-source data, such as honeybee images or sounds, and lacked comprehensive solutions. To overcome these limitations, this study presents a Cross-Attention-based Multimodal Neural Network (CAMNN) that integrates visual and audio signals in a shared deep feature space. CAMNN achieves an 85.8% accuracy, significantly outperforming the image-only models by 25.2% and audio-only models by 19.8% across four health categories. Additionally, it demonstrates strong prediction robustness, maintaining an F1 score above 75% across all four assessed health conditions. To provide a practical solution, an advanced system has been developed to offer near real-time live streaming of hive entrance activities and CAMNN-powered hive health assessment through a mobile



application. With access to real-time data and actionable insights, beekeepers can monitor their hives remotely, identify stressors, and quickly intervene to reduce colony losses.

Opti-Scan: A Low Cost, Non-Mydriatic Retinal Imaging System with a Three Stage Deep Learning Pipeline for Automated Diabetic Retinopathy Diagnosis

Paarth Nawani

Cupertino High School, Cupertino, CA

Diabetic Retinopathy affects 103.12 million people annually, with the number expected to climb to 191.0 million by 2030. Unfortunately, this issue disproportionately impacts those in low-resource regions, where 90% of all blindness occurs due to minimal basic eye care systems. Here, we propose Opti-Scan, an all-in-one non-mydriatic fundus camera integrated with a three-step machine learning pipeline designed for automatic diagnosis. For the fundus capture portion, we created a Raspberry Pi-powered system connected to a Raspberry Pi camera, 2 LEDs for fundus illumination, and an ophthalmic lens for magnification. We solely utilized off-the-shelf components to ensure that our device remained low-cost and accessible to all. Our machine learning pipeline consists of three key components. First, we employed a Super-Resolution Generative Adversarial Network (SRGAN), specifically the Real-ESRGAN, which we fine-tuned for retinal images to enhance image quality. Next, we developed an ensemble model by combining DenseNet121, InceptionV3, and MobileNetV2, rigorously testing and fine-tuning these pre-trained models to achieve optimal performance. Finally, we implemented a YoloV5 Object Detection model to identify and draw bounding boxes around potential lesions in the fundus, improving AI explainability. Ultimately, our ensemble model achieved an impressive accuracy of 95.2%, surpassing many current benchmarks. Opti-Scan, costing under \$150, has the potential to bridge the gap in global eye care inequality, offering a cost-effective and accessible solution for early detection and diagnosis of diabetic retinopathy in underserved regions.

10 Minutes of Action Can Prevent 10 Years of Destruction: Detecting Wildfires from Space Using AI

Ahvish Roy

Saint Francis High School, Mountain View, CA

Wildfires are among the most devastating natural disasters, threatening ecosystems, economies, and lives. The increasing frequency and intensity of wildfires, exacerbated by climate change and human activities, highlight the need for improved wildfire detection and forecasting. This study explores the application of Artificial Intelligence (AI) and deep learning to enhance the accuracy and efficiency of wildfire detection using geostationary satellite imagery. By leveraging geostationary satellite data from GOES and Himawari-8 AHI, along with Low Earth Orbit (LEO) reference datasets such as MODIS and VIIRS, this research introduces an AI-driven framework to enable real-time wildfire monitoring and prediction.

A Dual-Module Convolutional Neural Network (DM CNN) was developed to process both fire-related spectral signals and environmental variables, significantly improving wildfire detection by reducing false positives and increasing robustness across diverse geographic regions. By integrating both spectral and contextual data, the model adapts to varying atmospheric conditions, terrain types, and land cover classifications, ensuring more reliable fire identification in challenging environments. This dual-processing approach allows the model to distinguish real fire events from common false triggers, such as solar reflections, hot surfaces, and cloud edges.



Experimental results on the LA Wildfires of 2025 show the AI-driven wildfire detection system outperforms traditional algorithms, providing higher accuracy and faster detection times. The combination of real-time meteorological updates and AI offers a comprehensive wildfire management framework, capable of improving response times and mitigating fire-related damages. Future research will expand the training dataset for global wildfire scenarios as well as incorporate social media data into the system.

Molecular Arsonists: Degrading Oncogenic Transcription Factors to Reverse Tumor Immortality

Joshua S. Wu

Dublin High School, Dublin, CA

Mentors: Nicholas O. Stevers Ph. D and Joseph F. Costello, Ph.D., University of California San Francisco

Glioblastoma (GBM) is the most predominant malignant brain cancer in adults without prognosis improvement in decades. Nevertheless, 83% of GBM cases have Telomerase Reverse Transcriptase promoter (*TERT*p) mutations, enabling the GA-binding protein (GABP) transcription factor complex to bind and reactivate *TERT* expression, allowing the tumor to divide indefinitely. While directly targeting telomerase has systemic toxicity, targeting GABP may allow tumor-specific *TERT* silencing. Because targeting transcription factors with small-molecule inhibitors is nearly impossible, a novel approach is required. Last year, we designed a *GABPB1* dominant negative, reducing *TERT* expression in glioma cells. Still, because the construct was large and remained intact, it could reactivate *TERT*. To improve our approach, we devised a strategy for creating biologic-based Proteolysis-Targeting Chimeras (bioPROTACs) to target the GABP. Using GABPA, the binding partner of GABPB1 and GABPB2, we engineered a GABPA dominant negative by mutating key DNA-binding residues to alanine. We then utilized AlphaFold3.0 to identify the smallest GABPA capable of binding to GABPB1/2 via *in-silico* modeling. Finally, we functionalized this minimal GABPA-DN by attaching a Ubiquitin degrader (SPOP) or a lysosomal degrader (CMA) domain. We observed an 80-90% decrease in *TERT* expression and a near-complete degradation of all GABPB1 isoforms in tumor cells. Here, we present a strategy for the creation of biologic-based therapeutics targeting oncogenic transcription factors utilizing modern machine learning algorithms, validated using the master regulator of mutant *TERT* promoter-driven tumor immortality as a proof-of-concept, providing a powerful example for the potential applications it may have in other transcription factor-regulated diseases.

California Southern

The Power of Frequencies as a Treatment for Neurodegenerative Diseases: Which Sinusoidal Frequencies Impact Nematode Mutants Expressing ABeta1-42?

Chloe Chen

Brentwood School, Los Angeles, CA

Alzheimer's Disease and other related disorders have been increasing steadily as the population ages. The misfolding and accumulating proteins such as Amyloid-beta ($A\beta$) leads to neurodegeneration in these diseases. Available treatments are limited by invasiveness and side effects, raising the need to develop alternative therapies. The mutant strain *smg-1 CL2355* contains a human $A\beta$ transgene engineered into its pan-neuronal cells, causing impairments in cognitive function. This study observed the time for the organisms (N2 Wildtypes and *smg-1* hermaphrodites) to react in the form of backward sinusoidal locomotion, and the time for the organism to recover and return to the normal movement (forward-moving sinusoidal undulations),



when exposed to the airborne frequency spectrum (2s; 100Hz, 450Hz, 1-5kHz; 80dB SPL). The N2 reacted faster than the *smg-1* across all frequencies except 4000Hz, to which the *smg-1* reacted and recovered faster. Then, we investigated how the A β 1–42 protein in the *smg-1* developed over multiple generations of exposure to 4000Hz for 30 minutes and used the Congo Red stain to target the Amyloid-beta protein in the *smg-1* and N2 nine days after exposure. The buildup of Amyloid-beta1-42 plaques decreased in the *smg-1* after each generation, calculated by comparing the mean gray value in the Amyloid-beta plaque of *smg-1* and N2 over multiple generations of exposure to 4000Hz for 30 minutes. Identifying the effects of frequencies on the A β 1–42 protein may have implications for treating dementia and potentially extending one's sense of self and connections to loved ones.

Design and Characterization of Novel Imatinib-Loaded Nanoparticles for Localized Immunomodulation

Nathan Kang

Northwood High School, Irvine, CA

Mentor: Dr. Nisarg Shah, University of California San Diego

Anti-inflammatory drugs have been successful at reducing inflammation caused by autoimmune disease and allergies but often lead to a wide range of side effects due to their generalized immunosuppression that make patients more susceptible to infections. This study discusses the design and immunomodulatory effect of poly(lactic-co-glycolic acid)-poly(ethylene glycol)-maleimide (PLGA-PEG-MAL)-based nanoparticles as a carrier for imatinib, an immunosuppressive drug. These novel imatinib-loaded nanoparticles (ILNPs) improve targeted immunotherapy through localized and sustained drug release only in inflamed areas with high concentrations of autoreactive and hyperreactive cells. ILNPs were synthesized using nanoprecipitation and measured with dynamic light scattering (DLS) to have an average hydrodynamic diameter of approximately 34 nm with a low polydispersity index (PDI) of about 0.16. Lyophilization and UV-Vis spectroscopy results confirm consistent imatinib encapsulation across batches. In vitro human macrophage assays demonstrate that ILNPs promote M2 macrophage differentiation, decrease expression of CD86, and upregulate surface expression of the V-domain Ig suppressor of T cell activation (VISTA) protein, demonstrating the ability of these ILNPs to shift the phenotype of autoreactive and hyperreactive cells which can prevent the need for chronic drug usage due to the increased presence of tolerogenic cells that naturally favor an anti-inflammatory response. These ILNPs were made with a polymer containing a maleimide functional group, making these ILNPs capable of being functionalized with cysteine-containing antigens and allowing for cell-specific immunomodulation, demonstrating the potential of these particles to be an effective treatment for both autoimmune disease and allergies.

Revolutionizing Turbulence Studies: Novel Low-Cost Zero Mean-Flow Chamber Design and Physics-Informed Tensor Basis Neural Network

Aiden Kwon

Palos Verdes Peninsula High School, Rolling Hills Estates, CA

Teacher: Mark Greenberg, Palos Verdes Peninsula High School

Turbulence is a natural phenomenon that serves as an underlying principle for many other fields, ranging from astrophysical studies of star formation to climate change modeling. Due to its complex nature, understanding turbulence remains a classical physics problem. The goal of this project is to design, build, and test a novel zero mean-flow chamber for statistical turbulence measurements as well as develop an innovative Physics-Informed Neural Network (PINN) to improve turbulence modeling. It is hypothesized that the PINN will predict the Reynolds stress term more accurately than traditional NLEVM and LEVM methods.



Experimental apparatuses with zero mean flow are crucial to capturing pure turbulence characteristics and verifying statistical theories. The chamber utilizes 6 symmetrically distributed actuators and circular disk extensions to create both isotropic and anisotropic conditions. A low-cost Particle Image Velocimetry (PIV) system is developed to characterize turbulence of up to Taylor microscale Reynolds number 152. A PINN that reconstructs the Reynolds stress tensor and enforces realizability constraints was developed and applied to the closure problem. NASA's 2D converging-diverging channel flow dataset was used. The neural network incorporates a physics-informed loss function, invariant feature sets, and a hyperparameter sensitivity study.

The chamber design achieved a near-zero mean-flow condition with less than 1.5% error. The PINN achieved 97% accuracy for Reynolds stress predictions when compared to ground truth. These achievements emphasize the role that the new PINN and novel chamber system have for the future of turbulence physics, specifically in astrophysical and environmental applications.

Curcumin Alleviates Inflammatory Responses in an Animal Model of Systemic Inflammation

Tanya Mandyam

Westview High school, San Diego, CA

Mentor: Dr. Sierra Simpson, University of California, San Diego

Inflammation is the most common biological response in the majority of acute as well as chronic debilitating diseases and is a chief cause of morbidity. Current therapies for inflammatory diseases are limited to the chronic use of steroidal and non-steroidal anti-inflammatory agents, but this use is reported to cause severe adverse effects. I used an animal model of systemic inflammation and explored the use of curcumin as an anti-inflammatory plant-based organic supplement. I tested the hypothesis that severe disturbance in circadian rhythm (12-hour shift in day/night cycle in animals with 12L:12D photoperiod) would enhance inflammatory responses, and curcumin supplement would ameliorate these effects. I induced rhythm disturbance in rats that were fed vehicle control (almond butter) or curcumin orally (40 mg/kg/day in vehicle) and measured inflammatory responses via 3 procedures: pro-inflammatory cytokines in the plasma (by ELISAs), the size of Peyer's patches on the gut (by ImageJ), and the gut microbiome composition of feces samples using metagenomics (by Qiime2). My results indicate that the curcumin supplement decreased plasma pro-inflammatory cytokines by 70%, Peyer's patch size by 50%, and inflammatory microbiota by 75% compared to the vehicle group (all p 's < 0.05), confirming its anti-inflammatory effects. Mechanisms include a reduction in the pro-inflammatory cytokines TNF- α , IL-6 and CXCL1, the size of the Peyer's patches, and pro-inflammatory microbiota, proteobacteria. Therefore, my results could be used to test effects of long-term curcumin supplement on various inflammatory diseases associated with pro-inflammatory cytokines and protobacteria (inflammatory bowel disease, metabolic disorders and cancers of the gut and bladder).



Chicago

Predicted Territory of *Muntiacus vuquangensis* in the Annamite Ecoregion Under Forecasted Environmental Conditions to Establish the Threat of Climate Change on Endangered Cervid Endemics

Elora Cianciolo

Oak Park and River Forest High School, Oak Park, IL

Supervisor: Allison Hennings, R.N., B.S.N., M.A.T. -Teacher at O.P.R.F.H.S.

Mentors: Dr. Mary Federici, Ph.D. (University of Maryland Baltimore County), Dr. Andrew Tilker, Ph.D. (Leibniz Institute for Zoo and Wildlife Research), and Dr. David Skole, Ph.D. (Michigan State University)

Anthropogenic climate change has created immense alterations to atmospheric and environmental conditions, with global-scale ramifications. Existing research addresses the issue of altering ecosystems and consequences such as biodiversity loss and food shortages by investigating novel solutions to mitigate further impacts. Few experiments investigate the impacts of climate change on food scarcity for specific species of animals. This gap limits the broader conservation applications of such research in biodiversity hotspots such as the Annamite mountains region, which extends across habitats in Cambodia, the People's Democratic Republic of Laos (Laos PDR) and Vietnam. In this experiment the total viable territory of *Muntiacus vuquangensis* (*M. vuquangensis*), or the large-antlered muntjac (LAM), within protected areas in the Annamite ecoregion (AE) was calculated by projecting availability of its habitat for the years 2030, 2050, and 2100 based on the survival of its predicted diet plants to establish the impact of rising temperatures on this species. It was discovered that by 2100, there would be 0 km² of viable LAM habitat compared to ~ 3779.88455332 km² of target areas ≤ 1250 masl. To increase the validity of these findings, further research involving more real-world conditions is needed.

Ecdysone Used to Induce a Hyperandrogenism Phenotype in *Drosophila melanogaster* as a Basis for a Novel Invertebrate Polycystic Ovary Syndrome Model

Abigail Falkoff

Oak Park and River Forest High School, Oak Park, IL

Supervisor: Allison Hennings, R.N., B.S.N., M.A.T.-Teacher at O.P.R.F.H.S.

Mentors: Dr. Anna Benrick, Ph.D. (University of Gothenburg), Dr. Marc Tetel, Ph.D. (Wellesley College), Dr. Laura Torchen, M.D. (Ann & Robert H. Lurie Children's Hospital of Chicago)

Polycystic ovary syndrome (PCOS) is the largest contributor to infertility in women. PCOS contributes to serious health problems due to the overproduction of androgen in females, leading to miscarriages and infertility, as well as an increased susceptibility to type 2 diabetes mellitus. The etiology of PCOS is unknown. However, to control the variety of symptoms, several approaches exist; these include using oral contraceptives, making changes in diet and exercise, as well as using the drug metformin. Although researchers currently use vertebrate models induced with PCOS-like phenotypes, the development of a reliable vertebrate model requires research over multiple generations, which is expensive and time-consuming. This experiment developed a novel invertebrate model for PCOS, using *Drosophila melanogaster* (*D. melanogaster*), induced with PCOS-like phenotypes utilizing various amounts of ecdysone in their diets. *D. melanogaster* were tested over three generations to determine the impact of ecdysone diets on fertility with respect to egg laying. The results demonstrated a statistically significant reduction in egg production (one-way ANOV $p < 0.0001$) when ecdysone levels in the fly media were increased by, respectively, 10µl and 40µl. The results of this experiment provide support for the effectiveness of ecdysone as a method of inducing PCOS-like fertility changes in *D.*



melanogaster, demonstrating the potential for a novel invertebrate model for studying PCOS. An invertebrate model that uses *D. melanogaster* and ecdysone would allow for a cost-effective and efficient way to study the syndrome.

Smartphone Biomarkers: Linking Motor Patterns to ADHD

Niyathi Girish

William Fremd High School, Palatine, IL

Attention-Deficit/Hyperactivity Disorder (ADHD) is a prevalent neurodevelopmental condition, particularly among adolescents, that is often challenging to diagnose accurately. Current diagnostic approaches, which rely heavily on subjective self-report surveys, frequently result in overdiagnosis and misdiagnosis due to their inability to effectively differentiate overlapping symptoms. This study aims to explore whether motor patterns, captured through passive sensing using smartphone accelerometers and gyroscopes, can serve as an objective biomarker for ADHD among high school students. Data was collected from participants using a smartphone app that logged accelerometer and gyroscope readings over a 24-hour period. These data were correlated with scores on the Hyperactive/Impulsive subscale of the Adult ADHD Self-Report Scale (ASRS). The findings demonstrated significant correlations between features such as mean angular velocity and variance in pitch axis with the participants' motor scores, suggesting that specific motor activity patterns may provide a reliable indicator of ADHD. Although this study did not directly assess neurochemical changes, such as dopamine fluctuations, emerging research highlights the role of dopamine in regulating motor activity via the nigrostriatal pathway. The motor patterns identified in this study may reflect underlying dopaminergic activity, suggesting a potential neurophysiological link to ADHD symptoms. Overall, the findings support the feasibility of using passive motor data from smartphones as an objective tool to identify ADHD, potentially reducing the rate of overdiagnosis and misdiagnosis. Future research should focus on further exploring these motor patterns in relation to neurophysiological processes to enhance the understanding and accuracy of ADHD assessment.

AIM: A Predictive System for Mitigating the Global Burden of Iron Deficiency Anemia Through Integrated Interventions

Catherine Ji

New Trier High School, Winnetka, IL

Mentor: Dr. Zhangli Peng, University of Illinois Chicago

Iron deficiency anemia (IDA) is a condition that affects over 1.2 billion people around the world. It disproportionately impacts children and women in low-resource regions. IDA reduces cognitive function, weakens immunity, and increases maternal and neonatal mortality. Our current solutions, including iron supplementation, have limited scalability and adherence.

This study explores a potential data-driven hypothesis that combines food fortification, nutrition education, and subsidy policies, which has the potential to reduce IDA prevalence while providing significant health and economic benefits. To test this hypothesis, we developed the Anemia Intervention Model (AIM), a predictive modeling system that evaluates the effectiveness of various intervention types under different scenarios.

AIM uses data from the World Health Organization, UNICEF, and the World Bank to assess IDA prevalence, economic impact, and intervention feasibility. Using Monte Carlo simulations, cost-benefit analyses, and demographic trend projections, AIM predicts that fortification programs alone could reduce IDA prevalence by 40%, saving up to \$15 billion annually in healthcare costs. This number could reach 50% when combined with education campaigns and subsidies,



ultimately preventing 2 million annual hospitalizations and improving global workforce productivity by \$5 billion. The model identifies challenges, like limitations in supply chains and cultural resistance, and establishes plans for improved intervention strategies and policy standardization.

AIM provides attainable, cost-effective, and scalable solutions to policymakers. These findings highlight that solving nutritional security and health equity requires committed efforts at the global level. Future work will involve real-time monitoring and adaptive policy frameworks to sustain progress in IDA long-term.

Early Risk Assessment of Autism Spectrum Disorder: A Novel Approach Using Microbial Biomarkers and Ensemble Classification Models

Amritha Praveen

Adlai E. Stevenson High School, Lincolnshire, IL

Sponsor: Dr. Susan Brontman

Autism Spectrum Disorder (ASD) is a prominent neurodevelopmental disorder that affects 1 in 36 children. This disorder is rapidly increasing in prevalence; however, it still lacks a reliable and objective diagnostic test. Clinical diagnostic criteria rely on subjective behavioral assessments, causing delays in intervention. This study hypothesizes that children with ASD have differentially abundant bacterial species in their gut microbiome compared to neurotypical controls using stool samples. If the gut microbiome composition differs between ASD and control subjects, it could suggest a potential gut-brain axis connection in ASD and identify potential biomarkers for diagnosis or therapeutic targets.

Using 16S rRNA sequencing data from stool samples of ASD and neurotypical control subjects, a comprehensive analysis was performed to identify differentially abundant bacterial taxa. The workflow included: data preprocessing and quality control, taxonomic classification of OTUs, and statistical analysis using differential abundance testing (Mann Whitney U test) to identify differences between ASD and control groups. Using the identified biomarkers, an ensemble machine learning classification model was developed to objectively assess the risk of ASD.

The hypothesis was supported as the findings revealed significant differences between the ASD and control groups including an increased abundance of *Prevotella* and *Lachnoclostridium* species, and a decreased abundance of beneficial bacteria like *Ruminococcaceae* and *Bacteroides*, with p-values < 0.0005 indicating statistical significance. Furthermore, the machine learning model trained with these biomarkers had a prediction accuracy of 0.90 +/-0.05 and ROC of 0.95 +/-0.02. This research can pave way for early diagnosis and targeted interventions for ASD.

Connecticut

A Novel Mantis-Shrimp-Based Smart Glove for Stroke Rehabilitation

Jingyan Liu

Choate Rosemary Hall, Wallingford, CT

Mentor: Shiyao Gu

This research discusses the design and development of a mantis-shrimp-inspired smart glove targeted at aiding stroke therapy. The glove combines soft and rigid materials in a hybrid exoskeleton system, imitating the dexterity and strength of the human hand through pneumatic actuation and silicone-based constructions. The designing principle of the finger borrows ideas



from the bio-structure of the Chitin of mantis shrimp. Mantis shrimp exoskeletons provide a feasible engineering solution to segment silicone fingers while balancing durability and flexibility. The fundamental feature of the device focuses on helping finger motions through regulated inflation and deflation, facilitating rehabilitation in stroke patients with poor dexterity. The glove supports a passive range of motion and active-assisted motion workouts, assisting in the restoration of hand function by facilitating natural finger motions with little force. The performance of the glove in bending and straightening the little and index fingers in wearable and non-wearable situations was investigated. The findings revealed that the portable exoskeleton permits controlled movement via progressive expansion and supports finger bending and extension. Pressure values during expansion indicate strong bending control at 80–90 units in useable conditions. Moreover, the glove demonstrated excellent handling skills, allowing one to softly grasp objects like water bottles and cups—qualities important for rehabilitation activities. High success rates for safe gripping without excessive force indicate the glove's practical use in therapeutic environments. The glove's ability to permit controlled holding and finger mobility presents a potential way of enhancing hand performance in stroke victims.

Development of a Simple Salivary Rapid Diagnostic for the Detection of Iodine Deficiency

Tyler Malkin

Greenwich High School, Greenwich, CT

Iodine deficiency is a global problem affecting millions of people. Iodine Deficiency Disorders (IDDs) lead to serious health consequences including birth defects, developmental disorders, intellectual disabilities, and depression. Iodine deficiency is easily treatable with iodine supplementation. However, current diagnostic tests are inconvenient and/or invasive, require expensive detection equipment, and must be processed in a lab. This research created a rapid diagnostic assay for the detection of iodine deficiency using patient saliva. It was created using newly synthesized gold nanoparticles (AuNPs) and sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) and utilizes a colorimetric method for iodine detection. AuNPs (~45nm) were synthesized and mixed with 1.6M $\text{Na}_2\text{S}_2\text{O}_3$, and the diagnostic assay reagents were calibrated to produce a color changing response at a specific iodine deficiency threshold of $0.036\mu\text{M-I}_2$. Above this threshold (normal saliva iodine content), a red/purple solution is produced. For iodine deficiency of $0.036\mu\text{M}$ or less, a blue solution indicates IDD. Correlation of the solution color change as a function of $\mu\text{M-I}_2$ is linear, so that test-color could be used for eventual iodine-in-saliva quantitation. The diagnostic assay was successfully tested in artificial saliva and produced the expected visible color change, verified by UV-Vis spectroscopy. The diagnostic assay is easily performed, returning rapid results without the need for a lab or expensive detection equipment. The anticipated cost for this test is \$2, which includes all needed reagents. It allows the most vulnerable populations to easily monitor iodine levels at home, so that IDD can be identified and treated before leading to serious and often permanent conditions.

Developing Autonomous and Adaptive Systems For Space-Exploration Robotics With Neuromorphic Frameworks and Artificial Intelligence

Rithvik Suren

Academy of Aerospace and Engineering, Windsor, CT

Teacher: Thomas Brown, Academy of Aerospace and Engineering

Space exploration represents humanity's greatest endeavor into unknown environments. However, we face challenges in developing independent, autonomous and adaptive systems as we continue to identify novel regions. Current AI-driven rovers, such as NASA's Perseverance, are constrained by SWaP (size, weight, and power), radiation-resistant hardware performance, and onboard processing limitations for SLAM. This research investigates the potential of



neuromorphic frameworks integrating Spiking Neural Networks (SNNs) with reinforcement learning (RL) to enhance power efficiency, adaptability, and radiation robustness for extraterrestrial exploration. Thereby, this novel design improves power consumption, radiation resistance, and robust real-time processing for upcoming rovers. The hierarchical system operates on a Raspberry Pi, leveraging event-driven computation akin to SNNs. Testing procedures included system performance tracking, radiation simulation, and action-space clustering evaluation. Results demonstrated a 30× reduction in CPU time and balanced resource utilization of 11% RAM and CPU, compared to traditional algorithms (RAM: 96.3%, CPU: 6%). t-SNE action-distribution visualizations revealed that SNN-PPO exhibited structured clustering and rapid adaptation, akin to biological learning. Radiation simulation testing confirmed system stability, a key requirement for planetary missions. A Welch's t-test comparing action-space clustering between SNN-PPO and ANN-PPO yielded $t \approx 7$, $p < 0.01$, confirming that SNN-PPO forms significantly more structured policies, reinforcing its advantage in decision-making under uncertainty. These findings highlight the framework's potential for increasing rover efficiency while operating in constrained environments. By demonstrating adaptive and power-efficient AI for space robotics, this work advances the development of compact, autonomous planetary rovers and sets the foundation for next-generation space exploration systems.

Next-Generation VTOL Drones: A Breakthrough in Tilt Mechanism and Modular Design for Optimization and Accessibility

Cooper Taylor

Greenwich Country Day School, Greenwich, CT

Mentor: Dr. David Handelman, Johns Hopkins University Applied Physics Laboratory

Drones are widely used in military and civilian applications, with VTOL (Vertical Takeoff and Landing) drones combining the vertical lift capability of multirotor helicopters with the horizontal cruising efficiency of fixed-wing aircraft. However, conventional VTOL drones face energy inefficiency, high production costs, and stability challenges during transition phases. This research presents a newly developed VTOL drone featuring a novel tilt mechanism that allows the same motors to function for both vertical lift and horizontal cruising, eliminating redundant components and significantly improving energy efficiency. Additionally, a fully modular design enhances adaptability, durability, and ease of maintenance. The prototype, weighing approximately 2.6 kg, was constructed at one-fifth the lowest cost of comparable conventional VTOL drones.

A review of peer-reviewed literature as of January 2025 indicates that no previously documented VTOL drone has implemented this tilt mechanism, let alone one that integrates both a modular design and an adaptive tilt system. Computational Fluid Dynamics (CFD) simulations validate aerodynamic efficiency, with an optimal cruise speed of 72 km/hr (45 mph), balancing lift and drag for extended endurance. This speed is comparable to fixed-wing drones while being significantly faster than multicopter drones. CFD calculations estimate a flight time of 105 minutes, aligning with the endurance of comparable fixed-wing drones.

Future advancements will incorporate AI-driven autonomous flight capabilities to enhance real-time decision-making and operational efficiency. This research sets a new benchmark in VTOL drone technology by improving propulsion efficiency, cost-effectiveness, and modular adaptability, paving the way for broader real-world applications.



Lipid-based Codelivery of Doxorubicin and siRNA PD-L1, as a Multi-function Chemo-immunotherapy, Selective to PDAC via its MUC1 Overexpression

Lula Wang

Greenwich High School, Greenwich, CT

Teacher: Andrew Bramante, Greenwich High School

Pancreatic cancer is the second leading cause of death, with 90% of occurrences as Pancreatic ductal adenocarcinoma (PDAC). Doxorubicin (DOX) is the leading treatment for cancers, functioning by blocking topoisomerase II, an enzyme essential for cancer cell division. However, chemotherapy penetration in PDAC is limited due to its dense stromal barrier and destructive tumor-microenvironment (TME). Herein, a pancreas-specific chemoimmunotherapy utilizing DOX, siRNA PD-L1, and MUC1 antibodies was designed for PDAC treatment. To begin, mPEG-b-PHEP were fabricated as the nanoparticle (NP) interior, exhibiting flow-core capability. These were loaded with DOX, which were later coated with an SiO₂ layer for stability. Chitosan was then added as a binder for the inclusion of siRNA-PD-L1, to inhibit the PD-L1 pathway, restoring immune activity. Finally, DOPE-Anti-MUC1 was conjugated to the NP-surface, to provide friendly delivery through the TME, with selectivity to the overexpression of PDAC cell-surface MUC1. DOX-siRNA-DOPE dissolution studies in normal extracellular fluid (pH 7.4) versus that of the PDAC-TME (pH 6.8) demonstrate 100% degradation of the DOPE outer layer within five minutes. HPLC analysis was used to subsequently demonstrate DOX-siRNA release, where 95% of a 20ug DOX-load was released within the same 5-minute period following introduction to a simulated PDAC-TME. To simulate DOX-siRNA-DOPE selectivity and function, an MUC1 ELISA-kit was modified using ATR-FTIR analysis, which highlighted adhesion of the NP's DOPE-Anti-MUC1 functionality to PDAC-MUC-1 overexpression. Finally, Giant Unilamellar Vesicles (GUVs) were created with fluorescently-labeled lipid-bilayers that mimic both normal and PDAC cells (with MUC1). DOX-siRNA-DOPE again targeted PDAC GUVs due to Anti-MUC1 selectivity.

DoDEA Europe

Optimizing Fuel Composition for Thrust in Pulsejet Engines

Jessie C. Brenay II

Kaiserslautern High School, Kaiserslautern, Germany

Teacher: Ken Robinson, Kaiserslautern High School

Pulsejet engines offer an exciting avenue for research due to their simple design and unique combustion cycle. This study investigates how varying fuel compositions of propane and butane impact thrust performance in a small-scale pulsejet engine. The hypothesis posits that 100% propane, due to its higher vapor pressure and ease of ignition, would outperform other mixtures in thrust output.

Experiments were conducted using a custom-built pulsejet engine and a precision thrust measurement rig. Three fuel compositions were tested: 100% propane, 100% butane, and a 70:30 mixture of butane and propane. Each configuration underwent three trials, and thrust was measured in grams. Results showed that 100% propane generated the highest average thrust at 320 grams, followed by the propane-butane mixture at 285 grams. 100% butane, while offering a higher energy density, produced the lowest average thrust at 250 grams due to its lower vapor pressure and reduced combustion efficiency.

These findings confirm that fuel composition significantly influences the performance of pulsejet engines. Propane's properties made it the most effective for consistent thrust, while the propane-



butane mixture demonstrated a balance of efficiency and energy output. Butane's limitations in ignition readiness affected its performance, though its energy density suggests potential benefits in specific scenarios.

This study provides insights into optimizing fuel choices for pulsejet applications. Future work could explore advanced designs to reduce variability and examine the impact of ambient conditions on engine performance, contributing to the broader understanding of pulsejet propulsion.

Mammograms and AI: Improving Accuracy, Accessibility, and Acceptance

Raegan Cayce

Sigonella Middle High School, Catania, DoDEA Europe

Teacher: Marsha McCauley

As carcinogens have become increasingly prevalent in everyday life through the growing accumulation of microplastics, harmful chemical usage, and other factors-- so too has cancer; breast cancer accounts for 30% of all female cancers, establishing itself as the largest antagonist of health in females. Unfortunately, although huge strides have been made in possible treatment avenues-- recently, the initial diagnosis, mammograms, have been incurring worldwide false-positives, not only decreasing accuracy but also the trust and likelihood of female patients returning for future mammograms, which may have detrimentally lethal effects. As false-positives coalesce with growing burnout among radiologists, the accuracy of mammogram analysis has decreased significantly. Notably, medical professionals have attempted to combat this via deep-learning artificial intelligence programs-- that complete the task of analyzing mammogram images. Additionally, disparities have always existed between rural and urban healthcare, these AI programs have found considerable challenges when analyzing mammograms of rural women, who are statistically more muscular. Recognizing the multitude of issues present in the current infrastructure of breast cancer treatment, especially for rural women... The researcher aimed to provide a solution of an improved AI algorithm catered towards rural women and their excess muscle tissue. By crafting a program cognizant of muscle tissue AND cancer tissue, as well as implementing a survey towards rural women; the researcher's hypothesis of improved accuracy and acceptance of AI in healthcare and an algorithm's accuracy was supported. This research has the potential to revolutionize current breast cancer treatment processes, particularly in rural communities.

Creating Emotional AI: Chatbot with Physician-Like Empathy

Alexandra Quintanilla

Sigonella High School, Italy

Teacher: Marsha McCauley, Sigonella High School

Used for diagnosis, preventative screening, treatment, and more, it is undeniable that Artificial Intelligence (AI) is necessary to the future of healthcare technology. Yet drastically, AI falls short of the empathy and compassion humans have. While this may seem un concerning in a screening sense, as AI continues to be used as a tool of self-diagnosis through chatbots, it is paramount for it to possess the correct skills displayed in physician-patient interactions. This research paper utilizes generative AI and python to create a more empathetic healthcare chatbot. Using both structured prompts and developer instructions, the chatbot is customized to mimic the compassion of human healthcare professionals. The AI is tested on the CARE Measure, a real test used to measure the empathy of healthcare providers. 50 data samples have been collected, and the researcher has found that the AI scored an average of 45.38/50 on the CARE Measure, in comparison to general practitioner scores of 46.53. When conducting Welch's T-Test, the



researcher found a P-value of $2.624(10)^{-7}$, which was significantly lower than the significance level, 0.05. With this, the researcher concluded that the null hypothesis was unsupported by the statistics, therefore the hypothesis was supported: AI chatbots incorporating advanced NLP score similarly or higher than human physicians in assessments of empathy areas where healthcare providers are few, or poverty prevents individuals from receiving proper healthcare, AI chatbots provide an accessible and cost-effective solution by delivering medical advice to those who need it.

Investigating the Impact of Geometric Properties on Airfoil Performance: A Study of Coefficient of Lift (Cl), Coefficient of Drag (Cd), Coefficient of Moment (Cm), and Stall Angle

Nicholas Vail

Sigonella Middle High School, FPO, AE

Airfoils are used in nearly every field of engineering, from aerospace to environmental applications, and their purpose is not always to generate lift. This study examines the effect of airfoil geometry on aerodynamic performance, specifically lift, drag, moment, and stall characteristics—key indicators of airfoil behavior. The study focuses on maximum camber and thickness, two of the four defining geometric characteristics. It was determined that camber or asymmetry generally increased lift and drag, while decreasing the moment force. In contrast, thickness had the opposite effect. However, both thickness and camber did not seem to have a significant impact on the angle at which the airfoil stalled. A better understanding of airfoils allows for the creation of more efficient machines that save energy, money, and time. This study specifically advanced the understanding of camber and thickness effects on airfoils in common use. It also examined stalls, a characteristic often overlooked due to its subjectivity and difficulty in determination. The study approached this in a nuanced way, incorporating only airfoils in use today and simulating them in a manner that better reflects real flight conditions.

Regulatory Uncertainty and Neurotoxic Residues in U.S. Foods: QuEChERS Analysis

Trent Wilkerson

Ramstein High School, Ramstein, AE

Teacher: Dr. Michelle Harrington

Since 1966, the organophosphate chemical Chlorpyrifos has occupied a controversial role in US agricultural production as a pesticide. With mounting pressure for the chemical's ban, however, a 2017 ruling found chlorpyrifos neurotoxic and imposed a zero-tolerance on the compound. Later policy then overturned this ban in 2023, creating widespread panic among industry professionals about the chemical's use. While the policy has since been revised to support the earlier restrictions, a nearly year-long gap in enforcement remains, making the neurotoxic chemical a potential threat to US public health. This study seeks to establish whether or not legal precedent as a means of controlling current use deterred the industry from Chlorpyrifos, measuring the chemical's content in ten historically saturated crops from various jurisdictions. To accomplish this task, the researcher coordinated with the CVUA Stuttgart Laboratory to conduct a QuEChERS test of the collected samples, lending in high-accuracy results.

Contrary to expectations, chlorpyrifos residues were largely undetected. However, high concentrations of chlorates and other hazardous chemicals were observed during a multi-residue analysis, raising questions about the future of American food safety. The absence of chlorpyrifos, too, suggests several potential vectors for precedent-based regulatory processes, as well as a cautious approach to future governmental administrations.



The researcher aims to use this data to advocate for further stability in regulatory frameworks, as well as caution against similarly dangerous and uninformed policy reversals.

DoDEA Pacific

QLC-Net: A Hybrid Quantum Support Vector Machine infused Convolutional Neural Network Approach to Detect Bronchogenic Carcinoma (Lung Cancer) in Pathological Slides

Miyeong Berran

Humphreys High School, Camp Humphreys, Republic of Korea

Teacher: Mr. Scott Bittner, Humphreys High School

Recently, medical professionals have been in significant decline due to lack of interest, yet the rising population is increasing this disparity of medical treatment ratio to patients. Especially for periphery regions, there is a lack of equipment and professionals ready to make proper diagnoses, oftentimes pathological slides are left for late diagnosis or are even never examined. This raises the question regarding the feasibility of utilizing artificial intelligence for the purpose of pathological slide biopsy diagnosis. In particular this study was focused on the disease Bronchogenic Carcinoma (Lung Cancer) and the utilization of a Quantum Support vector machine infused Convolutional Neural Network (QC-CNN). The alternative hypothesis was that the QC-CNN would have at least an 80% accuracy in identifying healthy from cancerous, and would be able to identify the subcategory of the cancer. This was proven by the experiment after a multitude of trials with various epoch numbers and learning rates that resulted in a final model and trial with the highest variables consisting of a sample of 200 pathological slides and a raw accuracy of 90% and overall machine accuracy of 93%. The high accuracy of these results help support the advancement of technology, and although it wouldn't be used immediately for patients, this can still be a valuable tool for educators and students alike who are studying pathology. Furthermore proving its accuracy assists in debunking some ethical concerns of AI, rather than replacing medical professionals this will only be assistance.

Electrifying Effects: Investigating Magnetic Field Influence on Plant Tissue Conductivity

Callie Green

High School, Camp Humphreys, Republic of Korea

Teacher: Mr. Scott Bittner, Humphreys High School

The impact of magnetic fields on plant growth is an emerging area of research that indicates positive effects on the various physiological processes of plants, including nutrient uptake, hormonal signaling, seed germination, and root development. In this study, the effects that magnetic fields have on the conductivity of potato tissue were investigated. It was hypothesized that potato tissue conductivity would increase when in the presence of magnetic fields. In this experiment, two potato slices were placed in separate dishes of 0.9 saline solution, with the experimental group being surrounded by two N35 magnets, each with a strength of approximately 12,200 gauss, while the control group was kept away from any magnetic fields. Data were collected from both samples every five minutes for 30 minutes for three trials. The conductivity measurements were compared, and findings demonstrated that the potato tissue exposed to the magnetic field exhibited higher electrical conductivity throughout the 30 minutes when compared to the control group for all three trials. This data supports the notion that magnetic fields influence the electrical conductivity of plant tissue, suggesting that magnetic fields can aid in plant growth as a whole.



Evaluating Natural Materials for the Reduction of Antifoaming Phenomena in Aquatic Environments

Chloe J. Lee

Humphreys High School, Pyeongtaek, South Korea

Mentor: Scott Bittner

Foam pollution significantly impacts aquatic environments, influencing factors such as pH levels, turbidity, salinity, and temperature, and disrupting aquatic life. This study aims to evaluate the effectiveness of natural materials as anti-foaming agents, with a particular focus on rice bran powder as a potential solution. Eight natural materials were tested: gardenia fruit powder, chlorella powder, sweet pumpkin powder, rice bran powder, oatmeal, ginger powder, kelp powder, and flour. Each experiment was conducted using a beaker containing 2 milliliters of foaming detergent, 150 milliliters of water, and one of the natural materials. The mixtures were shaken using a laboratory shaker for an equal duration. The results revealed a significant reduction in foam formation in specific natural materials compared to the control group. Among these, gardenia fruit powder and rice bran powder showed equivalent effectiveness, each achieving a mean foam reduction of 195 milliliters. Both materials shared the same standard error of difference (13.463), T-statistic (19.8684), and P-value ($P < 0.0025$) when compared to the control group. The findings support the hypothesis, demonstrating that rice bran powder, along with gardenia fruit powder, was the most effective natural anti-foaming agent tested.

The Effect of Clam Abundance on Microplastics in Marine Ecosystems

Lan Legros

Kubasaki High School, Camp Foster, Okinawa, Japan

Mentors: Mrs. Jillian Eastman, Ms. Grace Perrotta

Microplastic concentrations have been exponentially increasing since plastic's introduction in 1907 and its high utilization during World War I (1914-1918). With limited means of disposal, approximately 9 million tons of plastic are found annually in oceans. In efforts to decrease the abundance of microplastics in marine ecosystems, the purpose of this experiment is to measure the effects of clams on microplastic consumption to reduce plastic sea consumption, and offer a solution to microplastic pollution. Clams were placed in 1.75 liter tanks, immersed in Okinawan sea water for 3 days, and fed on a regular diet. The clams were then massed to have an initial mass for comparison. After 1 day, 2.5 g of blended plastic bottle caps were added, and left for the whole time in the tanks with the clams. The clams were massed again in order to compare their initial and final masses after the introduction of plastics in their environment. This determined the retention of microplastics within clam populations. It was found that clams with microplastic introductions had a greater average mass increase than those with no microplastic introductions placed in the same exact conditions with respective mass increases of 0.026 g, 0.03 g, and 0.032 g.



How Does the Percent Illumination of the Moon Relate to Sea Turtle Crawls in Okinawa?

Sakura Lopez

Kubasaki High School, Camp Foster, Japan

Mentor: Brittni McGuire, Churamura

This project seeks to understand the relationship between percent illumination of the moon and sea turtle crawls in Okinawa, Japan. The sun and moon's collective gravitational pulls create low and high tides that are most dramatic during new (0% illumination) and full moon (100% illumination) phases. During high tide the distance between the water and optimal nesting habitat is shorter meaning a sea turtle would use less energy during a nesting attempt. Using 2024 nesting season data collected by Churamura, statistics were applied to determine if there is a significant difference between the number of crawls that occurred in 5 different percent illumination groups of the moon: Group A (0-20%), Group B (21-40%), Group C (41-60%), Group D (61-80%), and Group E (81-100%). Group E was visibly higher, however, no statistical significance was found during analysis. Additionally, statistics were applied to determine if there is a significant difference in the crawl success rates of two percent illumination groups: 0-50% and 50-100%. The higher percent illumination group had a slightly higher success rate, but was found to be insignificant. By determining whether the percent illumination of the moon is related to sea turtle crawls in Okinawa, recommendations can be made to help Churamura better predict when crawls occur. While no significance was found, future repetition of data collection may provide more conclusive insights. Having a higher encounter success during Churamura's Turtle Walks will leave people with more meaningful wildlife experiences and improve public contributions to sea turtle conservation efforts.

Florida

Advancing Sustainable Citrus Greening Disease Management: A Comprehensive Eco-friendly Approach for the Management of *Candidatus Liberibacter asiaticus* using trunk injection of *Murraya koenigii* derived biological extract and its validation through precision agriculture tools

Tanishka Aglave

Strawberry Crest High School, Dover, FL

Teacher: Ms. Dianne Schroeder

Huanglongbing (HLB), or the Citrus Greening Disease (*Candidatus Liberibacter asiaticus*), is the most destructive citrus disease worldwide and persists in threatening the sustainability of the Citrus Industry in numerous regions. Currently, no pesticide is registered to cure this disease besides the antibiotic Oxytetracycline under the emergency label section 18. The curry leaf tree, *Murraya koenigii*, is highly attractive to the Asian citrus psyllid, *Diaphorina citri*, which vectors the bacterial causative agent of citrus greening disease, but it is not a carrier of disease. In this experiment, curry leaf extract was used to treat greening-infected trees through trunk injection, with Oxytetracycline as the standard control. qPCR was performed at the end of the experiment, exhibiting an increase in Ct value (10%) in curry leaves extract-treated trees and Oxytetracycline. NDVI index also showed more than a 15% increase, confirmed with canopy physical measurement where the plant height width increased by 7.5 % and 12%. The chlorophyll content was higher in curry leaves extract-treated plants by 23% and 4% as compared to UTC and OTC, respectively, and no difference was observed in stomatal conductance. Among the different rates (10%-30%) of curry leaves extract, 30% was found optimal. Based on the findings, curry leaves extract can emerge as an effective and sustainable solution for citrus greening disease management, bolstering the global citrus industry. The experiment will be repeated in the coming



season to validate the current findings, and experimental plants will be observed for the next two years as a continuation of this experiment.

From Canopies to Crypts: An Ecological Survey of the Distribution and Success of Zombie Ants in the Little Big Econ State Forest

Victoria Krupica

Oviedo High School, Oviedo, FL

Teacher: William J. Furiosi II

While 40% of all described species on earth are parasites, their role is still poorly understood in the ecosystem. This study focuses on the “zombie ant fungus”, *Ophiocordyceps camponoti floridani* as well as the recently discovered mycoparasite that infect *O. camponoti floridani* and their place in prairie hammock ecosystems in the southern United States. Observational data was recorded from the Little Big Econ State Forest to determine what ecological factors correlated with cadaver distribution. A visual analysis of cadavers was conducted to determine fungal morphology patterns, grade visible atrophy, and determine if there were any mycoparasites present. The data was analyzed against the ecological data to determine that fungal distribution may rely on factors such as height off the ground substrate species, and Tree genus. As well as uncovering a potential host plant relationship between the fungus and the substrate *Tillandsia bartramii*. This study reports that *O. camponoti floridani* graveyards have a strong potential to be used as a tool to indicate changes in canopy cover in prairie hammock ecosystems if monitored over time.

Design of a workflow generating novel broad-spectrum siRNA therapeutics targeting critical conserved RNA elements in the viral genome *in silico*: a study in Dengue

Akshay Kumar

School: American Heritage School - Broward Campus, Plantation, FL

Mentors: Dr. Juliana Caulkins and Dr. Anita Shaw

The likelihood of another COVID-19-level pandemic occurring within 100 years is currently predicted to be 17% and is expected to increase to 44% in the next six decades. Emerging pathogens pose significant threats to global health due to their potential to trigger catastrophic pandemics. Traditional drug development, requiring an average of 12-15 years and \$879.3 million per pathogen, is insufficient to combat pathogenic outbreaks, as demonstrated by dengue: despite infecting ~400 million people yearly and being endemic to >100 countries, dengue still lacks universal treatments. If a computational biology workflow is applied to the dengue virus's sequences and serotypes, then siRNA molecules targeting critical conserved regions of the viral genome can be designed and validated for effectiveness, safety, and broad-spectrum capability fully computationally. Generated siRNAs were filtered through stability, efficacy, conservancy, and specificity parameters. Molecular docking and dynamics analysis evaluated siRNA interactions with cellular machinery. Three siRNA molecules were identified as promising candidates for targeting all dengue serotypes, demonstrating optimal GC content (38.10-42.90%), binding free energies (-29.4 to -31.6 kcal/mol), and predicted efficacy (84.95-92.98%). siRNAs exhibited excellent conservancy across dengue serotypes (90-100%) with minimal off-target interactions (E-values 0.66-2.6). High molecular docking scores (-308.79 to -381.49) and confidence scores (>0.95) confirmed robust interactions with cellular machinery vital for genomic silencing. This workflow could advance the rapid and flexible development of broad-spectrum antivirals for further *in vitro* validation, potentially reducing development times by ~22% and costs by ~39%.



AI-Mediated Computational Analysis of RNA-Based Aptamers Targeting the CD133+ Glioblastoma Cells

Suvir Leekha Talamas

Windermere Preparatory School, Windermere, FL

Mentor: Gaurav Sharma, Eigen Sciences

Glioblastoma multiforme (GBM) is a highly malignant brain tumor arising from glial cells, known for aggressive proliferation, infiltration, and resistance to conventional treatments. The blood-brain barrier (BBB) further complicates treatment by preventing most drugs from reaching GBM cells. CD133, a transmembrane glycoprotein and cancer stem cell marker, is linked to tumor progression and therapy resistance. Aptamers, short single-stranded DNA or RNA molecules, bind to target proteins with high specificity and affinity. In this study, seven potential aptamers were designed to target CD133. I hypothesized that aptamer A would exhibit the strongest binding to CD133, inhibiting its activity and thereby impeding glioblastoma progression. The CD133 receptor structure was predicted using AlphaFold 3, generating a high-resolution model. Aptamers were initially designed using Vfold 2D for secondary structure prediction, followed by refinement with Vfold 3D for tertiary structure modeling. Docking simulations with HDOCK predicted aptamer-receptor interactions, while PLIP analysis identified key molecular interactions such as hydrogen bonds and salt bridges. To further assess binding specificity, the 3D-modeled aptamers were docked onto the transferrin receptor (TfR) using HDOCK 2.0 and validated through ScanNet. Binding affinity, analyzed via PDA-Pred, helped identify the most effective aptamer. Results showed that aptamer CD133a demonstrated strong potential, suggesting its use in dual-targeting strategies for enhanced drug delivery across the BBB. Additionally, virtual reality (VR) technology was employed to visualize molecular interactions, contributing to the development of more effective glioblastoma therapies.

Tree Rings as a Potential Monitoring Tool for Saltwater Intrusion

Alynza McBride

South Sumter High School, Bushnell, FL

Teacher: Emily Keeler, Wildwood Middle High School

Mentors: Scott and Tamera McBride

This project assessed whether slash pine tree (*Pinus elliotii*) ring growth could be used to track rates of saltwater intrusion. If ring growth of non-halophytic pine trees is impacted by saltwater, then tree rings could be used to track saltwater intrusion, since they would have smaller rings.

Tree cores were collected at eight sites along a coast-to-inland transect near the Lower Suwannee River. The independent variable was sample site distance from the Gulf of Mexico. The dependent variable was tree ring width. The control group consisted of duplicate cores collected from one tree at each site to determine if ring growth was consistent within individual trees.

Tree cores were collected using an increment tree borer, stored and dried in paper straws, mounted on wooden bases, and sanded to increase ring visibility. The cores were scanned, and ring widths were measured using photo-analysis software. The tree ring widths were compared between sites and to extreme high tide events.

The hypothesis was supported because tree ring growth declined following extreme high tide events, demonstrating that trees are useful for saltwater intrusion monitoring. After extreme high tide events, ring growth rates declined by more than 40% compared to the average growth of the prior four years. Declines persisted for up to four years. After Hurricane Dennis in 2005, site ring



width averages decreased by 46% to 60%. Saltwater intrusion impacts extended 25.6 kilometers inland from the coast. Rainfall was not a statistically significant driver of growth at six of the seven impacted sites.

Georgia

Synthesis and Docking of Drug Delivery Anthraquinonylalkanamides

Michelle Diep

Gwinnett School of Mathematics, Science, and Technology, Lawrenceville, GA

Teacher: Dr. Courtney Cox

Mentor: Dr. Ajay Mallia, Georgia Gwinnett College

Anthraquinones are naturally occurring organic compounds with antibacterial, anticancer, and immunomodulatory properties, yet their current pharmaceutical use remains limited. This research study aims to design and synthesize integrated anthraquinone-based surfactants that act as both drug agents and delivery systems. In light of limitations with existing drug delivery systems (DDS), including poor absorptivity and distribution, and material instability, the creation of a biobased DDS would further the understanding and synthesis trends of drug delivery. Three surfactants, 1-Anthraquinonyl dodecanamide (AQ12), tetradecanamide (AQ14), and hexadecanamide (AQ16), were synthesized by refluxing 1-Aminoanthraquinone with acid chlorides, with purification via column chromatography. It was hypothesized that these surfactants would demonstrate improved druglikeness and transport properties compared to existing DNA-targeting drugs. Characterization was performed via IR spectroscopy, revealing successful synthesis. In silico study was conducted through DNA docking. AQ12 showed the highest binding affinity ($S\text{-score} = -9.3050$), attributed to hydrogen bonding and groove binding. AQ14 and AQ16 had weaker affinities due to steric hindrance from longer alkyl chains. All three surfactants showed statistically greater binding performance compared to ellipticine ($p=1.51 \times 10^{-7}$). Druglikeness and bioavailability were assessed using SwissADME, with AQ12 and AQ14 meeting Lipinski's Rule of Five, but AQ16 not due to excessive lipophilicity. AQ12 is the most promising candidate for future drug discovery and optimization. This study highlights the importance of balancing amphiphilicity in designing effective drug transport mechanisms. Future work will complete characterization, conduct in vitro testing, and with a focus on limiting steric hindrance in surfactants by tuning alkyl chain length.

Multi-Color Magneto-Fluorescent Nanoarchitectures for the Targeted Identification of Exosomes of Triple Negative Breast Cancer

Pragathi Kasani-Akula

South Forsyth High School, Cumming, GA

Mentor: Dr. Paresh Ray, Jackson State University

Due to rising mortality caused by breast cancer, it is necessary to develop early diagnostic techniques for the rapid identification of multiple exosomes of cancer prior to metastasis. Triple negative breast cancer (TNBC) makes up 10-15% of breast cancers and is characterized by its lack of estrogen, progesterone, and HER-2 receptors. This lack of receptors leads to an absence of targeted therapeutics and higher mortality rates, underscoring the need for early detection for improved patient outcomes. Exosomes are extracellular vesicles found abundantly in the blood, containing biomarkers specific to their cell of origin. If the presence of specific exosomes of TNBC in the blood could be detected, then that would enable early further insight into cancer progression. In this study, we report the synthesis of magneto-fluorescent carbon dot nanoarchitectures for the identification of the Tenascin C, Amphiregulin, and Programmed Cell



Death Ligand-1exosomes of TNBC. The nanoarchitectures produced in this study would enable multi-exosome detection, a new avenue that could enable better insight into the behavior of the cancer, prediction of most effective treatment options, and insight into staging of the cancer. In this study, yellow, green, and blue carbon dots were prepared using orange peel, yellow melon, and cantaloupe organic material. The three carbon dots were coupled with amine functionalized Fe_2O_3 magnetic nanoparticles (MNPs) using the EDC/NHS coupling method. The MNP-carbon dot composites were conjugated with aptamers to form magneto-fluorescent nanoprobe with high quantum yields. The nanoarchitectures were then employed in mixed exosome environments, displaying good specificity enabling multi-exosome detection.

Multi-Branch Temporal-Spectral LSTM-CNN in Deepfake Audio Detection

Max Lee

Gwinnett School of Mathematics, Science, and Technology; Lawrenceville, GA

Teacher: Dr. Courtney Cox; Gwinnett School of Mathematics, Science, and Technology

Malicious deepfake media has been increasing steadily, with audio deepfakes posing an intensive cybersecurity and impersonation threat; multi-branch network machine-learning models have been overlooked in audio deepfake detection. Combined with multi-branch CNN, this project investigates perturbations to train a deep-learning algorithm to differentiate between bonafide and spoofed audio samples, aiming for the public standard of 82.5% accuracy. Spectral and temporal features were extracted through mathematical formulas from audio signals and resized to predefined fixed shapes using image-based extrapolation and compression, avoiding the traditional padding/truncating method which degrades data integrity. All features were normalized through amplitude normalization and aggregated into a list of arrays for the 11-branch CNN. Beta 1 used 75 bonafide and 75 spoofed files, while Beta 2 used 250 bonafide and 250 spoofed files; both used an 80:20 training-validation split. Beta 1 reached a peak validation accuracy of 74.13%, with p-value of $2.512\text{e-}35$ for chi-square test, indicating statistical significance. Beta 2 improved upon Beta 1, receiving a validation accuracy of 95.78% with p-value of $1.221\text{e-}32$, reaching the engineering goal. These findings indicate that the novel approach of multi-branch CNN combining both handcrafted and automatic feature extraction as input shows potential in improving audio deepfake detection. Future steps include implementing LSTM and applying audio transformations to mimic real-world conditions and distortions.

Nanocomposite Sodium Alginate Xerogel for Oil Spill Remediation Applications

Cain Patel

Woodward Academy, College Park, GA

Sponsor: Lesley Carnes, Woodward Academy

A calcium-crosslinked sodium alginate (NaAlg) nanocomposite xerogel was synthesized as a biodegradable sorbent for oil spill remediation. Due to the high surface energy of the base polymer, the xerogel was functionalized with silicon dioxide dimethyl silylate nanoparticles and stearic acid to amplify porosity and instill hydrophobic properties. This functionalization resulted in the cultivation of several desirable mechanical properties, such as aqueous flotation and high tensile strength. Carboxyl ($-\text{COOH}$), hydroxyl ($-\text{OH}$), and methyl ($-\text{CH}_3$) groups augmented crosslinking through the facilitation of ionic interactions, hydrogen bonding, and hydrophobic interactions to induce a three-dimensional (3D) network, resulting in gelation. The xerogel exhibited a maximum absorption of 5.6 (g/g) in canola oil (78.2 cSt) and demonstrated high selectivity in low-viscosity oils. The average variable cost of the xerogel was around 60 times less than the traditional production cost for aerogels. These results imply that economically feasible and reusable xerogel nanocomposites hold significant potential for oil recovery applications.



A Bioengineered Platform to Study Microplastic Pollution-Induced Cellular Pathologies and Discover Therapeutic Interventions

Anushka Sable

Chamblee High School, Chamblee, GA

Teacher: Ms. Regan Wilson, Chamblee High School

Mentor: Vijayakumar Velu, PhD, Assistant Professor, Department of Microbiology and Immunology, Emory University

Plastic pollution represents a significant global ‘One Health’ crisis impacting humans, animals, and the environment. Microplastics have been found in human blood and many tissues. Emerging evidence links microplastic exposure to blood clots, artery plaques, and tumor development, yet direct causal relationships with these pathologies remain unclear. This highlights the need for new model systems to study the adverse health effects of microplastic pollution and discover potential treatments.

In this study, I developed a novel ‘plasticoma’ platform using a 3D culture of human cells, fluorescent polystyrene microplastic particles, and an extracellular matrix that reproduces microplastic-induced cellular disorders *in vitro*. I found that blood myeloid cells, mainly intermediate and classical monocytes, actively phagocytose microplastics and become activated. These cells undergo aggregation and cell adhesion, forming plaque- or nodule-like lesions in the 3D cell culture. Similar structures are generated in a multicellular 3D model of immortalized human lung cell lines created for system up-scaling.

This reproducible system enabled high-content screening of therapeutics, identifying drugs with anti-adhesion and anti-inflammatory properties that mitigate microplastic-induced lesions. The results provided evidence of polystyrene microplastics’ plaque or tumor-like structure-causing effects. The tissue-like model generated is a self-assembled and flexible system that can be easily modified to incorporate additional cell types or components. The platform offers a simple, efficient, and economical tool for studying microplastic-induced pathologies and identifying new treatments. This versatile platform can stimulate further investigations, reduce animal use in microplastic research, and be modified to study other pollution-induced diseases.

Great Plains

Identification of Neurogenesis-Associated Genes and Proteins Altered by Early-Life Stress and Exercise

Elizabeth Rose Barnes

Shawnee Mission West High School and SMSD Biotechnology Program, Overland Park, KS

Teacher: Dr. Kenneth Lee

Mentor: Dr. Julie Christianson

Epigenetics is the study of how environmental stimuli affect gene expression without altering the DNA sequence. DNA methylation is an epigenetic mechanism in which a 5-methylcytosine group binds to the DNA impacting gene expression. DNA methylation in the mouse hippocampus can significantly alter ability to learn, process, and respond to events. Neurogenesis is the process in which new neurons are generated in the brain, and this process happens through adulthood. Environmental stimuli such as early-life stress and exercise can alter neurogenesis. However, the genetic mechanism that causes altered neurogenesis is unknown. My project aims to identify neurogenesis regulating genes that are being impacted by early-life stress and exercise. My



hypothesis is that if DNA methylation occurs from early-life stress and sedentary lifestyle, then neurogenesis-associated gene expression will be altered, with hypermethylation having lower gene and protein expression and hypomethylation having higher gene and protein expression. To test this hypothesis, I did bioinformatics on DNA methylation data from the mouse hippocampus, then I performed real time PCR to measure gene expression. I found four genes that were being altered by early-life stress and a sedentary lifestyle: *Disc1*, *Ror1*, *Atp1a3*, and *Hspg2*. In conclusion, I identified neurogenesis regulating genes that were being changed and could potentially be the cause of altered neurogenesis. I hope this research will provide a greater understanding of the genetic mechanisms contributing to altered neurogenesis.

Identification and Characterization of Antibiotic-Resistant Bacteria

Sahira Bhakta

Shawnee Mission Northwest High School, Shawnee, KS

Teachers: Zulma Perez-Estrella, Kenneth Lee

This research project aims to investigate the presence and diversity of Tetracycline-resistant bacteria in soil samples collected from local playgrounds, focusing on understanding the potential risks associated with antibiotic resistance in urban environments. Tetracycline, a widely used antibiotic, has been implicated in the spread of resistance among environmental bacteria, and urban playgrounds may serve as reservoirs for resistant strains due to human activity and contamination from various sources. Soil samples will be collected from multiple playgrounds across the Johnson County, Kansas area, and the presence of tetracycline-resistant bacteria will be assessed using culture-based techniques, followed by DNA plasmid extraction and concentration readings, gram-staining, and genome sequencing. Results of high antibiotic resistance activity within each playground's samples. Specific bacterial types will continue to be analyzed through BLAST Genome Sequencing. Findings will likely underscore the potential health risks associated with the spread of resistance in public spaces and emphasize the need for monitoring and controlling antibiotic contamination in urban environments to mitigate the emergence of resistant bacterial and fungal strains.

Perceptions of Gaggle: A Mixed-Methods Study on Digital Student Monitoring in Lawrence Public Schools

Lawrence Dao and Daniel Dao

Lawrence Virtual High School, Lawrence, KS

Mentor: Ms. Thu Nguyen

The use of AI-powered applications to monitor online student activities has grown in K-12 schools across the U.S. Since November 2023, Lawrence Public Schools have adopted Gaggle, an AI-based student monitoring tool. Over a year later, limited understanding exists surrounding how students—the primary subjects of this monitoring—and other stakeholders perceive Gaggle. Our study aims to explore community perceptions of Gaggle by engaging four key stakeholder groups. We hypothesize that (H1) awareness of Gaggle's use varies significantly among the groups; (H2) perceptions of its benefits and concerns differ across groups; and (H3) participants who perceive Gaggle as beneficial are less likely to express agreement with concerns about its psychological and trust-related impacts. In December 2024, we conducted a web-based mixed-methods survey using Google Forms, targeting high school students (n=223), parents (n=60), teachers (n=78), and staff (n=22). The survey evaluated participants' awareness of Gaggle, included Likert-scale questions to gauge perceived benefits and concerns, and featured an open-ended question for insights on the tool. The results fully supported H1 and partially supported H2 and H3. Students reported significantly lower perceived benefits and higher concerns than other groups. Qualitative analysis revealed a spectrum of nuanced perceptions, underscoring diverse impacts of student



monitoring. Concerns about Gaggie's effectiveness and accuracy were prominent across all groups, with students and staff expressing strongly negative sentiments. These findings raised critical questions about transparency, privacy, and broader implications of AI monitoring in education and highlighted the need for greater stakeholder dialogue when implementing such tools.

The Combinatorial Effects of "Forever Chemicals" on *C. elegans*' Development and Behavior

Cooper Grotzinger Frerichs

Shawnee Mission South High School, Overland Park, KS

The chemical class, Per- and Polyfluoroalkyl Substances (PFAS), first used in the 1940s for ScotchgardTM and TelfonTM has grown to be a chemical class of 12,039 variants. Recently, health concerns linking Perfluorooctane Sulfonate (PFOS), and replacement chemical Hexafluoropropylene oxide-dimer acid (GenX) to developmental toxicity have raised concerns about potential risks to the environment and human health. Unregulated manufacturing, commercial use, and disposal of PFOS and GenX have contaminated drinking, surface, and ground waters globally. In *C. elegans*, GenX is linked to developmental toxicity, developmental delays, and body size changes, however, little to none is known about the potential developmental toxicity of GenX in combination with PFOS. In this study, *Caenorhabditis elegans* is used as a model to study developmental defects of a binary mixture. We exposed *C. elegans* to treatments of PFOS and/or GenX at various concentrations. Developmental toxicity was determined by studying the Δ Growth and body length with a 95% confidence. We observed a development delay occurring in all treatments. However, especially the mixture sensitivity from L1 - L4 treatment significant reductions in both gradients were shown. At 24 hours, we observed a remarkable sensitivity to show a decrease Δ in growth after acute L1 exposure in the lower gradient range. This suggests that a binary mixture of PFOS and GenX has varying effects at a range of concentrations. These results revealed the possibility of synergistic or additive effects caused by mixtures. Therefore, it is essential to understand the defects associated with combinations of PFAS chemical class.

Quantification of Deep Vasculature Structure in the Mouse Brain Using Image Analysis

Raymond Jiang

Casady School, Oklahoma City, OK

Mentor: Dr. Stefano Tarantini, The University of Oklahoma Health Sciences Center

The cerebrovasculature plays a critical role in the pathogenesis of vascular cognitive impairment and dementia disease. Aging exacerbates susceptibility to these conditions due to structural and functional changes in the cerebrovascular network. This study employed advanced image processing techniques to quantitatively investigate age-related physiological differences in the cerebrovasculature of young and aged C57BL/6 male mice. Using ultrasound localization microscopy, high-resolution brain images were acquired and analyzed. Image processing methods, including segmentation and thinning, were applied to those images and subsequently revealed significant age-related alterations in cerebrovascular structures. Notably, vascular density was significantly reduced in the cortical and hippocampal regions of aged mice compared to young mice ($p < 0.05$). Similarly, the number of vascular branches in these regions was markedly lower in aged mice ($p < 0.001$). An analysis of vascular diameter distributions highlighted declines in both microvascular and macrovascular integrity with aging. These findings suggest that reduced vascular density, decreased vascular branch counts, and diminished microvascular and macrovascular networks in aged mice may result in decreased cerebral blood flow,



contributing to the development of vascular cognitive impairment and dementia. This study underscores the importance of targeting cerebrovascular changes in aging as a potential avenue for understanding and mitigating the progression of vascular cognitive impairment and related dementias.

Greater Washington, D.C.

Development of next-generation supercapacitors through high-performance nanocomposite electrodes

Anusha Agarwal

Thomas Jefferson High School for Science and Technology, Alexandria, VA

Mentor: Dr. Ethan C. Ahn, George Mason University

Supercapacitors, energy storage devices which combine the high storage capabilities of batteries with the ultrafast charge/discharge abilities of capacitors, play a pivotal role in energy systems. Due to this unique combination, supercapacitors will revolutionize electric systems through renewable energy grid stabilization, power backups for IoT sensors and communications, ultrafast charging for portable electronics, and even powering electric transportation during braking/acceleration. However, supercapacitors are currently outcompeted by batteries in terms of energy density, preventing widespread usage. Therefore, the present study investigates the use of aluminum-graphene covetics as the electrodes for high-performance supercapacitors. This material, created by infusing laser-induced graphene (LIG) with aluminum nanoparticles, boasts a high surface area and extremely low resistance, optimal for electrochemical applications. Various material characteristics such as aluminum percentage and graphene structure were optimized during covetic synthesis to deliver ideal performance. Electrical characterization of the supercapacitor devices revealed the sheet resistance of the aluminum-graphene covetic sample as $2.44 \times 10^{-8} \Omega/\text{sq}$, almost a 100% decrease from the $32.9 \Omega/\text{sq}$ sheet resistance of the pure LIG control sample. The ID/IG ratio of 1.34 from the Raman characterization revealed the defect-rich nature of the covetic material, and the I2D/IG ratio of 0.14 confirms the covetic material consists of multiple layers of graphene. The performance of the covetics showed a statistically significant reduction in resistance while retaining a highly porous structure, making them ideal for supercapacitor electrodes. These advancements pave the way for the next generation of supercapacitors, creating new possibilities for sustainable innovation.

Development and Refinement of a Novel Rapid Phage Screening Protocol to Accelerate Bacteriophage Discovery and Offer Alternatives for Antimicrobial Resistant Infections

Madeline R. Levorson

Thomas Jefferson High School for Science and Technology, Alexandria, VA

Mentor: Dr. Kathleen Morrow, Thomas Jefferson High School for Science and Technology

The World Health Organization estimates by 2050, antimicrobial resistance (AMR) deaths will outnumber cancer deaths. A solution to AMR is desperately needed and bacteriophages are part of the solution.

Lytic bacteriophages are bacteria-specific viruses that lyse and kill bacteria. Lytic bacteriophages, including bacteriophage cocktails, have had limited treatment roles in AMR infections since bacteriophages must perfectly match the patient's bacterial isolate and be available upon demand. Unfortunately, discovering patient-specific bacteriophages takes significant research time.



In response to the need for rapid bacteriophage treatment, I sought to develop and refine a bacteriophage discovery protocol and evaluate environmental bacteriophages for cross lytic bacteriophage activity.

A novel spectrophotometric Rapid Phage Screening Protocol (RPSP) was developed, patented, and enhanced to provide a fast inexpensive method to discover lytic bacteriophages from the environment. Further refinements were made with validation of RPSP v2.0 through iterative testing of known lytic bacteriophages, phage cocktails, and environmental samples against *E. coli* B. Time dependent decreases in optical density (OD) absorbance proved lytic bacteriophage activity. Additionally, this research suggests phage cocktails may not be necessary for treatment and may have antagonistic effects.

Furthermore, cross-lytic activity was displayed with all eight discovered bacteriophages against both *E. coli* B and *E. coli* K12. No lytic activity against six other bacteria was found.

RPSP v2.0, using portable laboratory equipment and protocols, allows for rapid discovery of novel lytic bacteriophages which will help ameliorate the AMR crisis by providing rapid bacteriophage discovery and personalized medical treatments to patients worldwide.

NanoDiffusion: An Ultra-Precision, Compact Powder Optimization System for Advancing Battery Performance and Nanoparticle Cancer Treatment

Oliver Wang

Thomas Jefferson High School for Science and Technology, Alexandria, VA

In the advancing sectors of nanoparticle cancer therapy and electrochemical energy storage, uneven particle distributions significantly stunt efficiency and performance. In cancer therapy, uneven distributions of nanoparticles lower the efficacy of tumor targeting. Similarly, in lithium-ion batteries, inconsistent electrode coatings deteriorate battery lifespan and performance while also fostering dendrite growth. My research presents NanoDiffusion, a novel particle distribution system designed to improve the uniformity of particle distributions. I hypothesize that NanoDiffusion enhances particle uniformity, improving treatment efficacy in nanoparticle cancer therapy, boosting battery performance, and enabling the creation of advanced metal alloys with superior properties. Designed to be adaptable across various materials and processes, NanoDiffusion is compact and versatile. The system utilizes microcontrollers and the ATmega238P chip for precise parameter controls; with the TMC2209 driver enabling microstepping, it is capable of rotational precision with control down to 0.007°. Carney Flow Tests, Electron Microscopy, and Ultra-Stable Plasma (USP) material property testing confirm that NanoDiffusion significantly improves the consistency and uniformity of powder distributions. The application of this technology in the processing of nanoparticles for cancer treatment has the potential to improve treatment efficacy, while its integration into the creation of lithium-ion battery electrodes could improve both the performance and longevity of batteries. Furthermore, NanoDiffusion has been used to produce metals with exceptional hardness and high melting points, while also improving the precision and capabilities of metal additive manufacturing. Through this, NanoDiffusion paves the way for designing specialized high-performance metal alloy parts with characteristics that surpass existing strength and durability limitations.



Hawaii and Pacific

Science of Autonomy: Optimal Path Planning

Amelie Chen

Pacific Horizons School, Pago Pago, AS

Mentor: Mrs. Karen Dizon

Science of Autonomy: Optimal path planning optimizes maritime navigation by analyzing environmental factors such as ocean currents to determine time-optimal routes in the ocean. I hypothesized this wasn't feasible given how vast the ocean and variables were. Using the Hamilton-Jacobi-Bellman (HJB) partial differential equation, reachability sets and fronts were calculated to find the furthest points a vessel can travel given ocean conditions. Simulations between Lisbon, Funchal, and Ponta Delgada were created to explore how vessel speed, direction, and currents affect efficiency. Results showed that higher current magnitudes aid propulsion, while high-vorticity areas challenge navigation. Faster speeds reduce travel time but increase energy use, while slower speeds improve fuel efficiency by using favorable currents. This study shows the importance of adaptive path planning with real-time data to enhance navigation efficiency and safety. However, while I conducted this research in Portugal, my goal as a Pacific Islander was to apply this knowledge to my home island of American Samoa. In response to the lack of data in the South Pacific, I built an underwater remotely operated vehicle (ROV) using repurposed materials to collect oceanographic data. The ROV, designed to measure water quality, temperature, and salinity, provided information that I plan on integrating into the path-planning algorithms. This research project has the potential to revolutionize maritime navigation, provide more efficient routes, empower local communities, and advance the field of ocean science.

Assessing the Impact of Invasive Cassiopea Jellyfish on Water Quality in He'eia Fishpond

Justice Kong

Kamehameha Schools Kapālama, Honolulu, HI

Invasive upside-down jellyfish (Cassiopea) pose a significant threat to the Native Hawaiian mariculture system, He'eia Fishpond, by competing with cultivated fish species and stinging workers. This study aims to investigate the effects of invasive jellyfish on water quality and characterize environmental conditions that may cause jellyfish stress and mortality. I hypothesized that Cassiopea jellyfish increase water turbidity in He'eia Fishpond, which may negatively affect phytoplankton growth, a food source for cultivated fish. To test this hypothesis, I set up three treatments in triplicate at He'eia Fishpond with 3 gallons of fishpond water, 1L sediment substrate, and an air bubbler: no jellyfish, one jellyfish, and three jellyfish. I measured the temperature, turbidity, dissolved oxygen, and pH of the water using a YSI sonde at 0, 1, 4, and 24-hour time points in two independent experiments. In the first experiment, turbidity was directly related to jellyfish density. However, in the second experiment, the highest density of jellyfish had lower turbidity than the negative controls; therefore, support for my hypothesis is inconclusive. Instead, two other water quality parameters showed consistent jellyfish density effects: incubations with jellyfish had significantly lower pH and dissolved oxygen than negative controls despite the air bubbler. These results demonstrate that invasive Cassiopea can have ecological impacts on He'eia Fishpond. The outcomes of this study will provide crucial insights into how invasive species can alter local ecosystems and may inform effective management strategies to mitigate their impacts on maintaining the health of He'eia Fishpond.



Raman Spectroscopic Detection of Microplastics in Fish Gills around O'ahu

Travis Osaki

Pearl City High School, Pearl City, HI

Teacher: Anthony Ferro

Microplastics, degraded from plastic products, have become a pervasive pollutant that severely impacts marine ecosystems and public health. This issue is especially critical in Hawaii, where the ocean is an integral part in the environment and culture of the local community. This study examines the accumulation of microplastics in fish gills, a key pathway for pollution to infiltrate marine ecological networks, posing a direct threat to human and environmental health. Fish samples from various species around O'ahu were collected and analyzed using Raman spectroscopy, a technique that accurately identifies and quantifies microplastics based on their unique vibrational signatures. The results showed that polypropylene and polyethylene were the most prevalent plastics found in fish, highlighting the widespread contamination in local waters. Fish from the northern and eastern regions influenced by the North Pacific Gyre and trade winds had significantly higher microplastic concentrations ($p < 0.05$). Additionally, bottom-dwelling species exhibited elevated microplastic levels due to their feeding behaviors and proximity to the ocean floor ($p < 0.05$). These findings emphasize the alarming scale of the microplastic problem which extends beyond environmental pollution to pose a serious public health risk, especially for communities in Hawaii who rely on fish as a dietary staple. Identifying these patterns of microplastic infiltration in our environments shows the urgent need for policy changes, improved waste management, and more solutions to reduce pollution. This study provides crucial data to inform conservation efforts and guide local and global actions to protect marine biodiversity and safeguard public health.

Aiptasia for Heavy Metal Decontamination

Leilani Phan

Kalani High School, Honolulu, HI

Heavy metal contamination significantly threatens coastal ecosystems, including Oahu's southern shores, due to urban runoff and industrial pollutants. This study investigates the potential of Aiptasia anemones for mitigating lead contamination in seawater through their metal-binding metallothioneins (MTs). Seawater samples from Magic Island, known for lead levels exceeding EPA safety limits, were analyzed to assess the capacity of Aiptasia to sequester lead. Over 14 days, Inductively Coupled Plasma Mass Spectrometry revealed a marked reduction in lead concentrations in tanks containing Aiptasia, compared to rising lead levels in tanks without the anemones. The results suggest that Aiptasia reduces lead concentrations via MTs and reactive oxygen species (ROS) mitigation, making them effective bioaccumulators. Beyond their ability to detoxify heavy metals, Aiptasia demonstrated resilience to environmental stressors, further supporting their feasibility as a bioremediation agent in polluted urban marine environments. Unlike chemical methods, which often introduce additional ecological risks, this natural solution offers a sustainable and cost-effective approach to improving water quality. Furthermore, the study highlights the urgent need for innovative remediation strategies, particularly in regions heavily impacted by industrial and urban runoff. The findings of this research indicate that Aiptasia could serve as a valuable tool in reducing the ecological and public health risks associated with heavy metal contamination. Future studies should examine their performance across a range of environmental conditions and contamination levels to validate their broader applicability in restoring marine ecosystems affected by metal pollution.



Exploring Marine-Derived Extracts as Ethical, Sustainable, and Cost-Effective Fetal Bovine Serum (FBS) Substitutes

Kian Kenneth Francisco Sanchez

University Laboratory, Honolulu, HI

Teacher: Ms. Jennifer Seki-Wong, University Laboratory School

Fetal Bovine Serum (FBS) is a staple supplement in cell culture, providing key growth factors that promote cell health and proliferation. Cell culture has been a cornerstone of biological science since 1885, advancing both basic and applied research. Unfortunately, FBS presents ethical, scientific, and economic challenges: ~2,000,000 bovine fetuses are sacrificed annually to produce ~800,000 liters of FBS, batch-to-batch inconsistencies hinder experiment replicability, and FBS can account for over 75% of cell culture costs. Thus, identifying viable FBS alternatives is essential for the sustainable future of biological science. Marine sources offer an exciting avenue as FBS alternatives because of their abundance of bioactive compounds and sustainable potential. Novel extracts derived from sea urchin roe (uni) and an invasive algae (*Gracilaria salicornia*), were evaluated as alternatives to FBS. Extracts were prepared at 5%, 10%, and 20% concentrations, and their impact on HEK293 cells assessed through cell counts, MTT assays, and microscopy over 72 hours. The 5% and 10% uni and 10% algae treatments showed promising proliferation, with cell counts statistically comparable ($p > 0.05$) to the FBS control. The 5% uni treatment exhibited the healthiest morphology, achieving up to 84.3% of the FBS control's cell density. Despite the proliferative success, the MTT assay showed significantly lower viability across all treatments ($p < 0.001$), suggesting the extracts may lack metabolic factors necessary for cell function. These findings highlight the potential of marine-derived extracts as FBS supplements, with further refinement and exploration needed to determine their full potential.

Heartland

GDF15 and FGF21 Improve Glucose Metabolism in Mice Lacking OPA1 in Brown Adipose Tissue

Erin W. Chen

West Senior High School, Iowa City, IA

Mentors: Renata Pereira Alambert and Joshua Peterson

Brown adipose tissue (BAT) has the potential to mitigate obesity and its complications via increased thermogenesis and the release of endocrine factors, which play a role in regulating systemic metabolism. It was previously shown that mice lacking the mitochondrial fusion protein optic atrophy 1 (OPA1) in BAT (OPA1 BKO) had an improved metabolism like increased insulin sensitivity and glucose clearance. These mice also had high levels of the proteins fibroblast growth factor 21 (FGF21) and growth differentiation factor 15 (GDF 15) in BAT and the serum. In this study, the hypothesis that FGF21 and GDF15 act together to improve glucose metabolism in OPA1 BKO mice was tested. To test this hypothesis, mice lacking OPA1, FGF21, and GDF15 in their BAT (TKO) were generated and tested for their glucose tolerance and then later, insulin sensitivity. The results showed that TKO mice had impaired glucose tolerance compared to the wild-type control, whereas their insulin sensitivity was similar. In conclusion, while GDF15 and FGF21 are necessary to maintain normal glucose levels in OPA1 BKO mice, they don't contribute to insulin sensitivity. Understanding how BAT-released endocrine factors like GDF15 and FGF21 contribute to the regulation of glucose metabolism is crucial for developing new therapeutic strategies targeting metabolic disorders.



Extracellular ATP Effects on Mac-T Cell Actin Distribution

James Peng

Cedar Falls High School, Cedar Falls, IA

Mentor: David McClenahan, University of Northern Iowa

Leukocyte migration into the bovine mammary gland is a hallmark sign of mastitis. The McClenahan lab has previously shown that the presence of extracellular ATP is associated with permeability changes in epithelial monolayers (Mac-T cells). It is thought that permeability changes are associated with actin cytoskeletal changes within the cell. To test this hypothesis, I treated Mac-T cells with various concentrations of ATP, after which a commercial kit was used to extract the globular/filamentous forms of actin. Protein electrophoresis followed by western blot comparison of band density using the software Image-J was then used to determine actin levels under the different treatment conditions. Significant changes in band densities were determined using ANOVA followed with a post - hoc analysis. Mac-T cell exposure to concentrations of ATP from 0.1 millimolar to 20 millimolars resulted in significant increase in G-actin levels within the cell. Overall, it appeared that exposure to extracellular ATP may be a mechanism that resulted in cytoskeletal changes in barrier epithelial cells, potentially assisting leukocyte movement into the lumen of the gland.

A Comparison of the Effects of H₂ Incorporation on the Stability and Opto-electronic Properties of ZnO and Mg:ZnO Thin Films

Caleb Rowe

Central City High School, Central City, NE

Mentor: Ned Ianno, ECE University of Nebraska Lincoln

The purpose of this experiment was to see how hydrogen (H₂) incorporation during production of thin films affects the stability and opto-electronic properties of various thin films. It was predicted that, with H₂ incorporation, resistivity of the film would be reduced. I reached this hypothesis through an extensive examination of other studies on this subject. As shown in studies such as that of Gottardi et al. incorporation of H₂, even as little as 3%, has an effect on the conductivity of a zinc oxide (ZnO) film, and additional H₂ incorporation increases the conductivity by multiple factors of 10 (2011). To extend Gottardi's study, rather than only using a ZnO target, a Mg_{0.1}:ZnO_{0.9} target was used, and samples were produced at various substrate temperatures. Devices were produced in a radio frequency (rf) sputtering system, which deposits thin films of materials using ionized gasses. The data show a difference in the stability of ZnO samples over time, and an overall reduction of both the Mg:ZnO and ZnO film resistivities. This is attributed to filling of oxygen vacancies by H species and an increase in carrier concentration, respectively, as seen in other studies (Shantheyanda et al. 2012, Chen et al. 2004). To extend this study it would be interesting to use targets of varying percent compositions of Mg, use different methods of H₂ incorporation such as water vapor, and sputter films with varying substrate temperatures, as well as measure resistivity at regular intervals.



Hippocampal Volume in Alzheimer's Disease: OASIS-1 Dataset Analysis

Noah Shin

Ames High School, Ames, IA

Mentor: Katherine Koenig, Cleveland Clinic

This study utilized data from the OASIS-1 database, comprising 416 right-handed subjects aged 18 to 96, with 3-4 T1-weighted MRI scans per participant. The analysis focused on individuals over 60, including 91 Healthy Controls (HC) and 95 with mild cognitive impairment (MCI) or Alzheimer's Disease (AD), excluding younger HC datasets and outliers with moderate dementia (CDR=2). Brain parcellation was performed using FreeSurfer (i.e., open-source software) to measure hippocampal volume, adjusted for gender and brain size differences using Atlas Scaling Factor (ASF). I hypothesize that there would be a negative correlation between bilateral hippocampal volume and Clinical Diagnosis Rating scores. To test this hypothesis, a multiple linear regression model controlling for age, sex, and CDR scores was used to examine hippocampal volume differences between groups. Results showed significant volume reductions in AD and MCI groups compared to healthy controls. The study also found that CDR scores predicted hippocampal volume, confirming the association between hippocampal atrophy and cognitive decline in AD. Education levels differed significantly between groups, suggesting a potential protective role against AD. The findings imply that hippocampal volume could serve as an early indicator and biomarker for AD risk and progression. However, limitations include the cross-sectional nature of the study, focus solely on hippocampal volume, and potential confounding effects of education. As OASIS data includes a longitudinal dataset, examining these brain changes with multiple assessments would be worthwhile to see these groups' structural changes and clinical diagnoses over time.

Deep Learning for Crop Health: An Automated Approach to Systematic Corn Gray Leaf Spot Assessment and Management

Henry Zou

Johnston Senior High School, Johnston, IA

Mentor Professor Jian Jin, Purdue University

Gray Leaf Spot (GLS), caused by the fungal pathogens *Cercospora zeae-maydis* and *Cercospora zeina*, represents a significant challenge in corn production, resulting in annual economic losses amounting to billions of dollars. Conventional methods for assessing GLS severity are limited by high labor demands, subjectivity, and frequent inaccuracies. This study investigates the application of deep learning for automating GLS severity assessment, focusing on comparing the performances of a multi-model detection framework utilizing YOLOv8 Computer Vision Model and U-Net Convolutional Neural Network (CNN) to human experts in terms of accuracy and consistency. The YOLOv8 model was first utilized to extract leaf regions and disease type, followed by the U-Net CNN model to segment GLS lesions and calculate percent severity. The models were trained on the PlantVillage and Corn Disease & Severity datasets containing corn leaves infected with various diseases. The YOLOv8 model achieved precision accuracies of over 0.97 in classification of disease type, while the U-Net model demonstrated F1 accuracies of 0.89 in segmentation of diseased lesions. GLS severity assessments produced by the models showed a strong correlation and exhibited even higher levels of consistency than expert human evaluations, potentially making it a reliable tool for automated disease assessment. A third LLM model was integrated for field-application, providing tailored management strategies based on data from the first two models. Future studies will focus on integrating machine learning methods with field and greenhouse applications, obtaining an integrated disease score from multiple leaves and plants, and exploring their applications in other plant diseases.



Illinois

Hybrid Quantum-Classical Model for Molecular Generation: Integration of a QCBM and LSTM to Identify Novel Ligands for A2a Receptor

Sidharth Brahmandam

IMSA-RISE Stem Research Institute, Aurora, IL

Supervisors: Dr. Somya Anjur, Dr. Sudhir Brahmandam

Mentors: Mr. Timothy Holtan, Dr. Jagan Parepally

Drug discovery is a challenging, expensive, and time-consuming process often spanning a decade and requiring an investment of at least \$2.5 billion. Further, Drug discovery targeting complex proteins like the A2a adenosine receptor which is related to neurodegenerative diseases such as Parkinson's is challenging because of the vast chemical space of drug-like molecules, often theorized as 10^{60} molecules. This study hypothesized that a hybrid quantum-classical approach, integrating a Quantum Circuit-Born Machine (QCBM) and a Long Short-Term Memory (LSTM) network, could effectively model molecular distributions and generate novel molecules with high binding affinity for the A2a receptor.

This model first expanded a dataset of 10 known inhibitors with the STONED SELFIES algorithm, randomly mutating a training set of molecules while preserving their chemical validity. These molecules were converted into their binary Morgan Fingerprint, representing a high dimensionality probability distribution. The QCBM then learned from this data and represented this distribution as pure quantum states, which was the input to an iterative LSTM that generated novel compounds based on the features extracted from the QCBM. Finally, a docking simulation was used to produce the binding affinity of the generated molecules, and the three best performers were presented as the results.

In conclusion, this work establishes a novel methodology that combines the advantages of classical and quantum computing, successfully generating a number of molecules with high binding affinity to the A2a receptor. By accelerating drug discovery pipelines, such approaches could address unmet medical needs, improving outcomes for millions lacking effective treatments.

Human Glioblastoma Cancer Stem Cells Differentiation by Retinoic Acid: A Potential Therapeutic Strategy

Meher Garg

Springfield High School, Springfield, IL

Teacher: Dr. Sowmya Anjur, PhD, IMSA RISE STEM Research Institute

Mentor: Dr. Victoria Fox, PhD, Pathways to Stem Cell Science, Torrance, CA

Glioblastoma is an aggressive and fatal brain cancer, with a median survival of 15 months despite current treatments. Conventional therapies focus on eliminating cancer cells, but alternative strategies are needed. Retinoic Acid (RA), a vitamin A derivative, is known to induce cellular differentiation and is successfully used in treating Acute Promyelocytic Leukemia. However, its effects on Glioblastoma stem cells remain unclear. We hypothesized that RA could promote the differentiation of human Glioblastoma stem cells into neurons, potentially offering a novel therapeutic approach. LN-229 and U87-MG Glioblastoma stem cells were treated with RA at concentrations of 1.25, 2.5, 5, and 10 μM in media containing either 2% or 10% Fetal Bovine Serum (FBS). After 24 hours of incubation, cells were treated for five days, fixed, and stained with DAPI (stains all cell nuclei) and TUJ1 (beta tubulin antibody) to assess neuronal differentiation under fluorescence microscope. Cells were stained for viability using FDA (fluorescent diacetate).



Our study showed that RA effectively induces differentiation of Glioblastoma stem cells into neurons with U87-MG cells exhibiting a stronger response than LN-229. RA at 2.5 and 5 μM induced differentiation in both cell lines, with the most pronounced effect observed at 5 μM in 10% FBS. Lower concentrations (1.25 μM) inhibited cell growth, while higher doses (10 μM) led to cell death. The combination of 5 μM RA and 10% FBS yielded the best differentiation, highlighting its potential as a therapeutic strategy. Further in vivo studies are warranted to explore its clinical applications in Glioblastoma patients.

Wet Avalanche Prediction Based on Weather Patterns in the Going-to-The-Sun-Road Corridor of Glacier National Park using Machine Learning

Avirag Hosakote

Illinois Mathematics and Science Academy - Research, Inquiry, Skills, & Experimentation, Aurora, IL

Mentor: Dr. Sowmya Anjur, IMSA

Wet snow avalanches are incredibly hazardous, so predicting them and their destructive force size is crucial to protect lives, and this study seeks to do so by using weather data. Machine learning techniques can detect patterns in the weather that influence avalanches but aren't widely used. This study sought to better predict wet avalanches and their destructive force than previous approaches. The study area was the Going-to-the-Sun-Road corridor in Glacier National Park, a popular attraction prone to wet avalanches. Wet slab and glide snow avalanches were categorized together due to sharing similar causes while wet loose avalanches were predicted separately. Avalanches are affected by weather conditions over several days, so a sliding window input was used. The Long Short-Term Memory (LSTM) model was chosen for classification due to its ability to learn patterns over long periods of time. If a day was classified as an avalanche-day, it was sent to an XGBoost model that was trained to predict the maximum destructive force of any avalanche that would occur that day. This study tested different parameters for the LSTMs. The presented wet loose LSTM model predicted 90% of avalanches and had a total accuracy of 79% while the WS+GS LSTM model predicted 98% of avalanches and had a total accuracy of 80%. The XGBoost model for the wet loose avalanches had predictions close to the actual results, although the WS+GS XGBoost wasn't as accurate. Overall, these models perform better than previous attempts and could mitigate the harmful effects of avalanches.

Water World Exoplanet Atmospheric and Spectral Data Analysis via Thermodynamic Modeling and Unsupervised Machine Learning

Marcus King

Governor French Academy, Belleville, IL

Mentor: Dr. Laura Schaefer, Stanford University

Teacher: Mrs. Christine Stewart, Governor French Academy

Recent discoveries like GJ 9827 d's water-rich atmosphere have brought to light an understudied class of exoplanets—water worlds. The discovery of water in this exoplanet atmosphere simultaneously showed current telescopic capabilities while demonstrating a need to understand this planet class better with many similar discoveries soon likely. The current understanding of water world exoplanet detection is limited by models—through modeling exoplanetary processes, astronomers develop expectations and can optimize their searches accordingly. Water worlds are currently only known by their key atmospheric signature, water vapor, and due to this many planetary scientists have suggested that these worlds would be exceedingly hard to identify based on atmospheric spectroscopy. This study confronts this problem by developing 1.5 million data point resolution thermodynamic models of water world atmospheres relative to pressure and temperature (via equilibrium chemistry), using these to create a database of over 5,000 synthetic



spectra. A K-Means clustering algorithm is trained to identify different water world subtypes in the spectral dataset, and several new atmospheric tracers are identified from three main clusters such as carbon dioxide, sulfur dioxide, and hydrogen fluoride. This study also, in tandem, develops an analytical pipeline for modeling exoplanet atmospheres given initial conditions at a higher resolution than any previous study. This study marks a notable advancement in the modeling of these water world atmospheres.

Novel Interactions of Lexical Frequency and Visual Stimuli During Word Retrieval

Sohum Mehta

Illinois Mathematics and Science Academy, Aurora, IL

Mentor: Dr. Julien Dirani, Carnegie Mellon University

Speech production has long been the focus of neurolinguistics, where concepts are associated with their respective words, a process called word retrieval. Though defined, current research lacks focus on identifying how visual stimuli can affect speech production speeds, which if understood can contribute to theoretical applications in optimal learning. Thus, this research investigates lexical frequency (how common a word is), finding novel interactions with priming influencing word retrieval in pictures vs words. Data was collected through a previous study where 24 native English speakers completed a naming experiment featuring 50 concepts (25 animals, 25 tools), each presented equally and randomly as pictures and words. Lexical frequency metrics were employed from publicly available data through the English Lexicon Project (ELP), and trials were filtered to include only correct responses. Analyses were conducted using OLS regression and mixed-effect models, examining the main effects between modality (words vs pictures), frequency bins (high vs low), and semantic category (animals vs tools). The results showed statistical significance for all interactions. Pictures were named slower overall by ~162 ms, signifying pictures go through a pre-lexical selection stage, that words skip as they rely on overt reading. Notably, the novel interaction hypothesized of high-frequency effects masking evocative priming in pictures was statistically supported, meaning, pictures go through both priming and lexical selection. These findings contribute to significant theoretical understandings in psycholinguistics, introducing awareness of the extent of priming for English Language Learners (ELLs). Moreover, the differences in lexical frequency allow for tailored natural-language processing, optimizing responses.

Indiana

The Cognitive Effect of Hearing Loss on Anxiety and Insomnia

Norah Ahmed

Evansville Day School, Evansville, IN

Teacher: Ms. Ashley Moran

This research investigated the relationship between insomnia, anxiety, and hearing loss, with a focus on determining whether hearing loss exacerbates anxiety and insomnia in individuals. Motivated by the pressing issue of chronic insomnia in adults, especially those with disabilities, the study sought to assess the psychological dimensions of sleep disturbances in the context of hearing loss. Employing the Insomnia Severity Index (ISI) and Hamilton Anxiety Scale (HAM-A), data was collected from 100 participants with hearing loss through online support groups. The hypothesis was that because anxiety increases in hard-of-hearing people, a higher rate of insomnia correlates with anxiety as a main factor. Results indicated a substantial association between hearing loss and an elevated likelihood of insomnia (53%) and anxiety (61%). Notably, the data yielded a moderate correlation ($r=0.4223$) between anxiety and sleep patterns. These



findings emphasize the imperative need to address mental health concerns in the hard-of-hearing and deaf community, highlighting the impact of chronic stress on sleep. The study underscores the necessity for tailored interventions and support systems for individuals with hearing loss. The research contributes valuable statistics to existing literature and prompts further exploration into the intricate connections among insomnia, anxiety, and hearing loss.

Experience-based neural tradeoffs in perceptual sampling vs. predictive processing in the visual domain

Sean Borneman

Bloomington High School South, Bloomington, IN

Mentor: Dr. Evie A. Malaia, University of Alabama, AL

Sensory inference and predictive processing, in human neural activity, play a critical role in higher-order cognitive processes. However, the neurobiological bases of predictive processing are not well understood. This study used electroencephalography (EEG) to track participants' response to sign language and reversed sign language videos, to test the hypothesis that the frequency-following response (FFR) of the brain to the visual signal quantifies both behavioral comprehension and frequency of perceptual sampling for continuous visual input. In this study, I used the FFR metric to address two questions. First, I used machine learning to assess the relevance of specific frequencies and regions of interest to brain state classification accuracy. The results highlighted a significance of predictive processing time windows for sign language comprehension and biological motion processing, and the role of long-term experience (learning) in minimizing prediction error. Second, I used neural coherence to optical flow and PCA to assess age-related changes in neural processing. The findings indicate a general slowing of perceptual processing in older adults while increasing the duration of prediction time-window in language comprehension, likely due to accumulated language experience. Together these two findings improve on current models of understanding how the human brain learns, explain how people process visual information, quantify predictive processing based on neural data, and show the impact of language experience on brain function.

Making Every Component Count: Using the Shapley Value to Improve Win Ratio Analysis

Valerie Fu

Carmel High School, Carmel, IN

Clinical trials often utilize composite endpoints to provide a comprehensive evaluation of a treatment's effects by combining multiple related outcomes into a single measure. While traditional methods, such as time-to-first-event analysis, are widely used, they face limitations, including equal weighting of components, disproportionate influence of non-fatal events, and neglect of recurrent outcomes. The win ratio has emerged as an alternative, prioritizing outcomes by clinical importance and offering greater flexibility. However, it provides limited insight into the contributions of individual components to the overall treatment effect.

To address this gap, we develop the SEWRA (Shapley-Enhanced Win Ratio Analysis) algorithm, which integrates the Shapley value, a concept from cooperative game theory, into win ratio analysis. SEWRA fairly allocates the total treatment effect across the components of a composite endpoint, reflecting their relative contributions within the context of the overall win ratio. This approach enhances the interpretability of the win ratio and provides a deeper understanding of the treatment's impact on individual outcomes. Through simulations and case studies, we demonstrate how SEWRA offers a nuanced framework for analyzing composite endpoints, complementing existing methodologies and addressing their limitations. Our work aims to



advance the analytical tools available for clinical trial data, promoting more informed decision-making and improved patient outcomes.

Topology Optimization and Machine Learning Based Parametric Optimization Techniques: A Comparative Study with Physical Validation

Ankur Kapileshwar

Carmel High School, Carmel, IN

Mentor: Lyle Regenwetter, MIT

Topology optimization (TO) and Parametric Optimization (PO) are two fundamental structural optimization (SO) techniques. The aim of this study is to understand how these two techniques (TO and PO) stack up against each other from a variety of perspectives - (1) time taken for optimization, (2) manufacturability, (3) real-life adherence to simulated results, and (4) overall stiffness - by using the problem case of a cantilever beam as the basis of comparison. For this cantilever beam application, both TO and PO are evaluated and compared in a systematic manner on 3 different volume fractions (VF) of beams - 30%, 50%, and 80%. PO is conducted using surrogate optimization as opposed to simulation in-the-loop optimization. Most importantly and uniquely, the results achieved via software simulation for both PO and TO are then validated in a real-world physical setting. The simulated versus physically validated results are compared for all six TO and PO optimized cantilever beams. Through this comparison, it was found that the percent errors between the simulated and physical displacement for the 30%, 50%, and 80% TO/PO beams were 45.5%, -6.6%, -1.5%, 33.7%, 2.4%, and -0.1%, respectively. It was found that - for the chosen cantilever beam application - (1) TO is faster and shows better compliance, (2) PO is more manufacturable and shows better predictability between software simulated and physically validated results. Moreover, for both TO and PO, the 50% and 80% VF beams show good alignment between simulated and physical results.

How does APC influence CAF and Tumor Cell Interaction

Brianna Marable

Marian High School, Mishawaka, IN

Mentor: Dr. Jenifer Proserpi

Triple Negative Breast Cancer (TNBC), named after all three negative receptors, is a dangerous subtype of breast cancer (Grasset, Eloïse). My experiment focuses on TNBC cells that have the tumor suppressor, adenomatous polyposis coli (APC). It also focuses on cancer associated fibroblasts (CAFs) due to their abilities to increase tumor cell interactions. In my studies, I will use them to make a CAF-conditioned media to place over the cells. Ultimately, I will determine if the tumor cell interactions (proliferation and migration) will be influenced when CAF-conditioned media is placed onto the APC-KO cell lines. If you add CAFs to APC-KO cell lines then you will have an increase in tumor cell interaction because when CAFs are introduced to cancer cells, the tumor cell interactions will increase.

To answer my question, I performed a proliferation assay, migration assay, and western blot. The proliferation determined how quickly the cells reproduce, the migration determined how quickly the cells reconnected when split apart, and the western blot determined expression for both Cyclin D1 and STAT3 proteins. My graphs overall had no significance. This means no samples had a noticeable change. Specifically, there was no change in the tumor cell interaction of the APC-KO cell lines when CAF-conditioned media was added which proved my hypothesis incorrect. With this knowledge, I would like to expand on my research by discovering why there was no significance and treat my cells to a chemotherapy drug before the experiment to determine if there is a significant change after.



Intermountain

Growth Curve of *Mannheimia haemolytica*

Kinzey Clark

Hellgate High School, Missoula, MT

Mentor: Dr. Sobha Sonar, Montana State University

Teacher: Mrs. Willow Affleck, Hellgate High School

Mannheimia haemolytica is a bacteria involved in respiratory infections in ruminant species, often working in tandem with other bacteria to cause co-infections. Pneumonic mannheimiosis is caused by one of these co-infections, with *Mycoplasma ovipneumoniae* functioning as a predisposing agent, and *Mannheimia haemolytica* acting as the secondary, symptomatic infectant. This infection has caused a high mortality rate in Rocky Mountain bighorn sheep, and currently has no treatment or preventative. From preliminary observations, I hypothesized that the bacteria's growth phase would spike on the lower half of eight hours post inoculation. I began by isolating a singular colony of *Mannheimia haemolytica* and placing it in a broth media, which was placed in an incubator shaker for eight hours. Each hour, two samples were taken to measure the optical density and make dilutions for blood agar streak plates. I observed the growth phase of the bacteria and saw a spike in both the optical density and colony forming units of the samples between hour three and four, with the optical density rising from 0.085 to 0.279 and the colony forming units spiking from $1.12E\pm09$ to $5.57E\pm09$. These results confirmed my expectation of *Mannheimia haemolytica*'s growth phase spike occurring in the first half of an eight hour timeframe, and suggests that further experimentation with this bacteria should be performed between hours three and four after inoculation for more easily measurable results. Moving forward with the knowledge gained from research, preventative and treatment options will be experimented on within this timeframe.

Methylene Blue Film Fabrication for Piezoelectric PFAS Detection

Jordan Chong

Davidson Academy, Reno, NV

Mentor M. Rashed Khan, University of Nevada, Reno

Per- and polyfluoroalkyl substances (PFAS), nicknamed "forever chemicals," are widespread contaminants in water. Current methods of detecting PFAS are expensive and burdensome, so new low-cost detection methods are in high demand. Certain new methods incorporate the active properties of the low-cost chemical methylene blue ($C_{16}H_{18}ClN_3S$), but these methods are limited in sensitivity due to their colorimetric basis. To improve upon previous implementations, this project incorporates methylene blue in a distinct mass-based mechanism that allows for PFAS sensing at higher sensitivity and similar cost. The active technology is a quartz chip that vibrates when an electric current is applied (a phenomenon called piezoelectricity). This chip is coated in a thin film of methylene blue, which binds PFAS molecules; as PFAS accumulates on the film, the resulting change in mass alters the chip's vibrational properties, allowing nanogram-level detection. Using calibrated water solutions, a detection model is obtained that would allow PFAS sensing in unknown water samples, and the model's performance is tested on real tap water samples spiked with PFAS. This innovation has the potential to aid PFAS-affected communities by facilitating water safety measurements, and may be modified to sense other contaminants.



RIOK3, an Unexplored Therapeutic Target Against Cancer

Maxime Diaz

Hellgate High School, Missoula, MT

Teacher: Ms. Willow Affleck, Hellgate High School

Mentor: Dr. Brent Lyda, University of Montana

Pancreatic ductal adenocarcinoma (PDAC) is a lethal cancer with a five-year survival rate of only 13% and no effective treatment options. RIOK3, a kinase implicated in immune modulation and cytoskeletal structure, has emerged as a promising therapeutic target due to its overexpression in PDAC and association with tumor invasiveness and metastasis. In this project, I tested the hypothesis that selective pharmacological inhibition of RIOK3 would reduce PDAC cell proliferation and viability by disrupting its phosphorylation. This study evaluated the pharmacological inhibition of RIOK3 using two synthesized compounds, DX809 and DX812, designed to selectively target RIOK3 by mimicking ATP to interact with its active site. Caspase-3, MTS, and LDH assays were utilized to assess the drug dose response by cells in the form of apoptosis, metabolic activity, and general cell death. At one nanomolar, DX809 significantly decreased cell proliferation and disrupted cytoskeletal integrity, while DX812 effectively induced cell death. The observed morphological changes of cell rounding and detachment, further suggested cytoskeletal disruption as a critical mechanism of action. Notably, the selectivity of these inhibitors implies reduced side effects in chemotherapy by sparing non-cancerous tissues with low RIOK3 expression. The findings highlight RIOK3's role in sustaining cancer cell viability and its potential as a novel therapeutic target. Future studies should explore combination dosing of DX809 and DX812, their efficacy in vivo, and their potential interactions with other atypical kinases such as RIOK1 and RIOK2. These results offer a promising pathway for developing selective, effective treatments for PDAC and other cancers expressing RIOK3.

Reducing Hydrofluorocarbon Emissions: Fine-Tuning Phase Transitions in Two-Dimensional (2D) Perovskites for Solid-State Refrigeration

Ian Jake Kim

West High School, Salt Lake City, UT

Principal Investigator: Dr. Connor Bischak, University of Utah

Common refrigerants in cooling systems contain hydrofluorocarbons (HFCs), potent greenhouse gases with global warming potentials 1000x higher than CO₂, which leak into the atmosphere upon disposal of cooling equipment. A solid-state alternative to HFCs, storing thermal energy in a solid-solid phase transition, could prevent harmful climate effects. 2D perovskites are promising solid-state refrigerant candidates due to their molecular tunability and significant enthalpy changes (ΔH_{trans}): the magnitude of thermal energy absorbed/released when their organic cation layer undergoes an order-to-disorder phase transition upon reaching their phase transition temperature (PTT). This study explored the thermodynamic effects of alloying different molar ratios of halides (Br, Cl⁻), organic cations of varying lengths (9,10,11-carbons), and metal cations (Cu²⁺, Mn²⁺) in 2D perovskites to provide novel methods in 1) leveraging maximal ΔH_{trans} to maximize perovskite cooling efficiencies 2) exerting control over the PTT to develop perovskites for specific temperature applications, to ultimately find viable solid-state refrigerant alternatives. Through halide and organic cation alloying, the PTT was fine-tuned over a 12°C and 21°C range. I found that a 100% Cl⁻ and 100% longer organic cation (10,11-carbons) composition yielded the maximal ΔH_{trans} . This composition achieved a cooling efficiency half that of conventional HFCs. Findings showed that by further lengthening the organic cation, higher ΔH_{trans} could be leveraged



to reach ΔH_{trans} of HFCs. Additionally, blending Cu^{2+} and Mn^{2+} had minimal effect on the PTT and ΔH_{trans} . Through halide and organic cation alloying, this study provided novel principles to develop solid-state refrigerants for specific temperature applications, while maintaining comparable cooling efficiencies to HFCs.

The Effectiveness of Neurological Soft Sign Examinations in Diagnosing a Concussion

Shaelyn Tolleson Knee

Hellgate High School, Missoula, MT

Mentor: Dr. Bill Rosen, Rosen Rehab

Teacher: Mrs. Willow Affleck, Hellgate High School

Current sports concussion exams are largely founded on either expert consensus (e.g., SCAT6) or the examiner's discretion. A mTBI results in subtle damage to a diffuse network of neuronal connections involving the cortex, brainstem, cervical cord, and/or autonomic nervous system. This often leads to a cluster of abnormalities that cannot be localized to a specific lesion. Therefore, it was hypothesized that soft sign examinations may be a better way to assess these patients. In this study, we used the Spokane mTBI Examination (SME), a soft sign exam originally developed for high-velocity mTBIs, to determine the average number of soft signs in a healthy, never concussed, athletic female population and compared their results to those from their peers who had previously been concussed but had 'recovered'. The SME includes several visual, motor, balance, autonomic, and reflex tests that can be conducted at the bedside or sideline. We have studied 52 female athletes between the ages of 14 and 18 who attend Hellgate High School in Missoula, MT. The average number of soft signs observed in the healthy population was 1.5, with a range of 0-4 and a standard deviation of 1. Individuals scoring 4 or more soft signs were more than two standard deviations beyond the mean. In our mTBI population, the average soft sign score was 9.8, with a range of 5-15. The SME shows promise to serve as a standardized tool for assessing all mTBI patients, improve diagnostic accuracy, and guide treatment interventions.

Kentucky

Vita Seat - An innovative Smart Toilet Seat with built-in UV sanitization for health monitoring of cardiovascular and respiratory diseases

Annika Chadha

duPont Manual High School, Louisville, KY

Mentor: Mr. Armentrout, Director, LVL1 Makerspace, Louisville, KY

Cardiovascular and respiratory diseases make up 2 of the 3 leading causes of death globally amounting to more than 23 million people. More than half of these deaths are preventable with early diagnosis and treatment. 80% of the mortality occurs in low-income nations where preventative health monitoring is non-existent. Many barriers exist in people accessing health care facilities. Regular monitoring of cardiovascular and respiratory health is sorely lacking. This is due to lack of easy and unintrusive monitoring technologies. Additionally, there has been an increase in health issues related to prolonged sitting on toilet seats. To combat these issues, a highly affordable smart toilet seat, the Vita Seat was developed, to monitor ongoing health vitals like pulse, blood oxygenation, and temperature. The toilet seat contains a set of 6 sensors with Arduino Nano microcontrollers that track the key vitals. An embedded RP2040 in the seat cover contains a set of 3 circuit boards with 4 UVC LED lights each to sanitize the toilet. A timer in the Vita Seat warns users of prolonged time on the toilet seat. Data from multiple Vita Seat users was tracked and displayed using a mobile app. This completely unobtrusive mechanism of gathering data while people perform daily routines and reporting abnormal readings provides an early



warning mechanism for people to seek immediate medical help. The average Vita Seat readings for the pulse rate, blood oxygenation and temperature were on average **99% accurate** compared to the expecting readings, making this a valuable health tracking tool.

Development and Validation of an Accessible, Rapid Calcium Monitoring Diagnostic

Chaturya Paladugu

duPont Manual High School, Louisville, KY

Mentor: Sobha Bodduluri, University of Louisville

Currently, testing calcium in the blood requires a hyper- or hypocalcemic patient to visit a healthcare facility and wait 4-5 days before receiving results. This is not only inconvenient but also time-consuming, especially in situations that could be life-threatening. Therefore, through repurposing off-the-shelf methods of current ion measurement practices, it is proposed that a more efficient and less time-consuming way of measuring calcium levels is plausible. This study is conducted to investigate the making of an efficient, accessible calcium measuring device using repurposed ISEs for the challenges of timely diagnosis and accessible management of calcium disorders like hypocalcemia and hypercalcemia. Whereas most of the currently used methods of diagnosis, like the traditional laboratory tests and even ISEs, have issues with delays and accessibility, this study focuses on the creation of a portable and rapid testing solution. This project involves the development and testing of a reused ion-selective electrode (ISE) to quantify calcium concentrations in a rapid and accessible way, attempting to avoid the limitations of standard methods. In this work, a quantitative experimental method is used to develop an improvised ISE to achieve results within 24 hours and make it suitable for use outside the laboratory environment. The device's performance in timeliness, accessibility, and accuracy was also contrasted with the gold-standard HORIBA LAQUAtwin Ca-11. Results show quick results within the preferred timescale. While accuracy was promising in most experiments, with positive correlations to the gold standard, anomalous findings were realized in a single experiment, indicating that additional optimization is necessary.

RecuNet: A Novel, Low-Cost, & Automated Pipeline for the Spatiotemporal Prediction of Brain Tumor Recurrence

Gopalaniket Tadinada

North Oldham High School, Goshen, KY

Mentor: Dr. Jack Grinband, PhD, Columbia University

Gliomas affect 90,000 people annually in the United States and have 5-year survival rates as low as 7%, largely due to 5-year recurrence rates of 52-62%. Current MRI relies on contrast enhancement (CE) to visualize the glioma, which has several limitations: (1) tumor infiltration often extends far beyond CE margins; (2) After surgery, non-contrast enhancing tumor grows undetected & appears as “recurrence” in follow-up scans. Blood Oxygen Level-Dependent (BOLD) fMRI measures brain blood flow, which can be disrupted by the tumor microenvironment. Therefore, BOLD, combined with current imaging, could detect real-time tumor progression prior to radiologic “recurrence”, defined by CE. This project, RecuNet, aims to (1) establish a link between BOLD, non-contrast enhancing tumor, and recurrence, and use deep learning to (2) detect the non-contrast enhancing tumor and (3) spatiotemporally predict tumor recurrence. Both algorithms take standard (T1 + FLAIR) scans and BOLD fMRI as inputs. The detection algorithm uses a 3D-UNet Architecture with optimized loss functions and Attention Gated Networks (AGNs). The Prediction Model is a CNN that uses temporal-spatial convolutional layers and hybrid inputs to extract features in peritumoral regions. Preliminary detection results show an IoU of 94.1%, accurately detecting con-contrast enhancing tumor portions. The prediction algorithm has a 94.52% location accuracy and a mean average error of 5.3 days from recorded recurrence time,



significantly outperforming current methods. RecuNet nearly eliminates recurrence risk by visualizing the entire, exact tumor and accurately predicting areas with a high risk of developing tumor growth, saving money, resources, and lives.

Combating PFAS Contamination: A Preconcentration Method for Detection in Drinking Water

Wanda Wu

duPont Manual High, Louisville, KY
Mentor, Dr. Xiao An Fu, University of Louisville

Per- and polyfluoroalkyl substances (PFAS), nicknamed “forever chemicals,” are a group of harmful chemicals that are known to cause damage to the immune system and liver. Despite being found everywhere, including in drinking water, only 30 states have implemented PFAS regulations, only 11 of which include drinking water. Limited PFAS regulations is partly because PFAS usually exists in too low of concentrations to detect. Therefore, this research focuses on pre-concentrating PFAS to develop an on-site method for trace-level PFAS detection in drinking water.

In this study, perfluorooctanoic-acid (PFOA) was pre-concentrated by flowing 8 mL of a 0.25 ng/L PFOA solution through a sorbent in a microfabricated-chip, followed by elution with 800 μ L of phosphate-buffer solution (PBS). The solution was then run through a microfluidic sensor with two sandwiched gold electrodes, where a current was applied between the electrodes and the change in electrical impedance was used to quantify the PFAS present. A solution of 0.05ng/L PFOA was then flowed through the sorbents at the highest-performing flow rate to simulate real-world contamination levels. Three sorbents (carboxen, carbopack, and tenax) were tested at two flow rates (0.25 and 0.5 mL/min), and it was hypothesized that carboxen at 0.25 mL/min would have the highest capture efficiency due to the largest surface area and longer contact time. However, the research found that tenax at 0.25 mL/min slightly surpassed carboxen, indicating the importance of pore size of the sorbent in PFAS adsorption.

The Effect of Dectin-1 on Trained Immunity and Overall Immune Response of Macrophages

Ella Xing

duPont Manual High School, Louisville, KY
Mentor: Dr. Jun Yan

Cancer is a devastating and major problem that is difficult to treat. A new and promising idea of trained immunity suggests that following stimulation with an antigen/pathogen, innate immune cells will have increased responsiveness to subsequent challenges. Macrophages are innate immune cells that are important to the innate immune system. WGP is a type of β -glucan, a fiber recognized as an inducer for trained immunity with 4 receptors. One of these receptors is Dectin-1. In order to determine the role of Dectin-1 in trained immunity and overall immune response, bone marrow-derived macrophages were collected from mice and divided into four groups: WGP-trained Dectin-1 knock-out (WGP KO), untrained Dectin-1 knock-out (UNT KO), WGP-trained wild type mice (WGP WT), and untrained wild type mice (UNT WT). They were compared through the expression of CD80, CD86, MHC class II, and TNF- α , molecules that are released when macrophages are activated (activation markers). Though there was generally higher expression of the activation markers following WGP training, expression (and therefore activation) was significantly greater for the wild-type macrophages. Even without WGP stimulation, the wild-type macrophages generally had higher activation marker expression. These findings indicate that WGP-trained immunity largely depends on the Dectin-1 receptor, and Dectin-1 is critical for the



optimal activation of macrophages. This study advances the understanding of how β -glucan-mediated trained immunity can be used for cancer immunotherapy.

Louisiana

Caffeine Mitigates Human Brain Cell Aging: Implications for Deep Space Exploration

Elaine Lu

Caddo Magnet High School, Shreveport, LA

Mentor: Xiaohong Lu, LSU Health Shreveport

NASA is preparing lengthy missions to the Moon and Mars. There is an urgent need for safe and effective countermeasures to protect space flight crew members for deep space missions. Epidemiological studies suggested that coffee consumption is associated with increased longevity, radioprotection, and neuroprotection against Alzheimer's and Parkinson's diseases. However, the mechanisms underlying these effects remain largely unknown. I hypothesize that deep space radiation can induce persistent DNA damage, leading to cell senescence and brain aging. Countermeasures targeting genotoxic stress, such as caffeine, can mitigate the risk. Using a genetic sensor of genomic instability, I have shown a robust increase of genomic instability, the foremost hallmark of aging, in mouse brains exposed to Moon and Mars mission-relevant doses of ground-simulated Galactic Cosmic Radiation (GCR). The first-ever brain map of genotoxic instability in mice was generated using light sheet microscopy volume imaging in cleared whole brains and mapped to Allen Brain Atlas. To search for countermeasures, I discovered that chronic exposure to radiation mimics and induces double-strand DNA breaks, ATM phosphorylation, and cell senescence in human-induced pluripotent cells differentiated neurons. Additionally, ATM inhibitors such as caffeine effectively reduced cell senescence via restoring autophagy and a Parkinson's disease-related protein. This research presents a novel approach for safely and effectively shielding human brains from ionizing radiation during NASA's deep space missions while also potentially contributing to treatments for abnormal aging and neurodegenerative disorders.

Neuroimaging Analysis of Cognitive Decline in Parkinson's Disease: A Gender Comparison

Vennela Malireddy

Caddo Magnet High School, Shreveport, LA

Mentor: Dr. Christina Ledbetter, LSU Health Shreveport

Parkinson's disease (PD) is a neurodegenerative disorder resulting from loss of dopamine-producing neurons in the substantia nigra. Motor symptoms include tremors, instability, and slowed movement, and non-motor symptoms include cognitive impairment, depression, and speech problems. Sex differences in prevalence, symptomology, and progression of PD have been reported. For example, men are 1.5 times more likely to have PD than women. Motor symptoms present later in women, but progression and mortality rate are higher in men.

This study investigated sex differences in cognitive domains with a focus on processing speed to test the hypothesis that males with PD experience greater cognitive deficits than females and decline at a faster rate compared to females. We found that PD was associated with a significant decrease in function across all cognitive domains. For PD, there was a significant group difference between males and females for processing speed and general cognition, with males performing worse than females. There was no significant difference between the rate of decline for males and females with PD.



This study also investigated dopamine levels, white matter integrity, basal ganglia structures, and regional gray matter thickness to determine a correlation to gender differences in processing speed. We found that dopamine levels were significantly correlated to processing speed, as well as gray matter thickness, however, there was no significant correlation with white matter integrity.

These findings support our hypothesis that men with PD experience greater processing deficits compared to women with PD, and this performance is related to dopamine and brain structures.

The Effect of Phonic Faces® on Decoding Accuracy in a Student with Reading Deficiencies

Claire McGuinness

St. Joseph's Academy, Baton Rouge, LA

Mentor: Dr. Janet Norris, LSU Department of Communication, Sciences, and Disorders

The purpose of this study was to determine whether the use of a unique alphabet called Phonic Faces® assists students with reading delays improve their decoding ability. The hypothesis was that the program Phonic Faces® will improve the child's decoding ability. First, the participant took pretest probes to measure his existing decoding abilities. After taking the pretests, the subject started the intervention which took place 3 times a week over the course of about 5 weeks. He would open Zoom and read the training words presented on the screen by the experimenter. After the student read the word, the Phonic Faces® would pop up on the screen, and the experimenter would elaborate on how to pronounce the word. At the end of every session, the experimenter would administer a probe which had 10 vowel-consonant, 10 consonant-vowel-consonant, and 10 consonant-vowel-vowel-consonant words to the student that he had to decode. After the intervention was complete, the subject was administered a posttest. There was an increase in the subject's VC and CVC scores throughout the intervention; this large gap between pretest and posttest scores for CVC shows that the increase in the student's decoding ability was statistically significant. However, since the VC were initially at a higher skill level, growth was not seen as significant. Since the subject was unable to decode any words in the control group, CVVC, it can be said that the growth in the VC and CVC categories was caused by Phonics Faces®, improving the child's decoding ability overall.

Investigating the Synergistic Role of IL-1 β and TGF- β in Endothelial-to- Mesenchymal Transition during Coronary Artery Disease

Aashni Shah

Caddo Magnet High School, Shreveport, LA

Mentor: Dr. Mabruka Alfaidi, University of Nebraska Medical Center

The endothelium, a layer of cells lining the inner wall of coronary arteries, contributes to blood hemostasis and healthy function of the heart. In coronary artery disease (CAD), endothelial cells (ECs) acquire changes in their functions in a process called endothelial-to-mesenchymal transition (EndMT). EndMT is a multi-stage phenotypic change by which ECs become pro-migratory, pro-proliferative, and profibrotic, contributing to plaque formation and arterial occlusion. It is understood that the cytokines interleukin-1 beta (IL-1 β) and transforming growth factor beta (TGF β) influence the progression of EndMT, but their specific roles are still not fully understood. We hypothesize that IL-1 β and TGF β uniquely impact endothelial cells and develop atherosclerotic plaques, and hope to identify potential biomarkers and therapeutic targets for developing new treatments.



In this project, human aortic ECs were stimulated with IL-1 β , TGF β , or both for 72 hours. Relevant EndMT markers were assessed by western blotting for protein expression, qRT-PCR for gene expression, and immunocytochemistry.

It was found that IL-1 β alone induces partial EndMT, upregulating inflammatory markers like IRAK1, IRAK4, and ICAM-1. This indicates its role in early vascular remodeling in CAD. TGF β alone upregulates smooth muscle actin (SMA) and downregulates CD31, promoting mesenchymal transition and fibrosis. Together, IL-1 β and TGF β enhance mesenchymal markers (Vimentin, SNAIL1) and suppress endothelial markers (VE-Cadherin, eNOS), accelerating disease progression.

IL-1 β and TGF β play distinct yet synergistic roles in promoting EndMT, with IL-1 β driving inflammation and TGF β inducing fibrosis. Targeting these pathways offers therapeutic strategies to slow or prevent CAD progression by mitigating EndMT and vascular remodeling.

Mitigation of Pressure Injuries: Inertial Wearable and Computer Vision Approaches

Maya Trutschl

Caddo Magnet High School, Shreveport, LA

Mentor: Dr. Steven Conrad, LSU Health Shreveport

Pressure ulcers, or pressure injuries (PIs) are localized areas of skin and/or underlying tissue decay that typically occur over bony prominences due to prolonged pressure or friction. These ulcers can range from a pink spot on the skin to exposed bone and tissue and can lead to increased morbidity and mortality. Detection and prevention of PIs is currently done manually by healthcare staff, necessitating an alternative approach to screening. The objective is to develop a tool that can identify the predispositions for PIs and create low-cost assistive devices for the individuals at highest risk.

Identifying patients at highest risk is done using MIT's MIMIC-III database of demographic and clinical features of a large patient data set, combined with data analytics and machine learning. Only the variables available in the first 48 hours of admission are used in the model. Mitigation is done using two complementary devices that help track the patient's position in a hospital bed. The first is a non-invasive camera monitoring system, and the second is an inertial wearable based on a microcontroller and gyroscope/accelerometer. These two devices detect and track the time a patient has been turned and alert to the need to reposition the patient to relieve pressure points.

This project developed a novel, highly accurate three-prong approach to PI mitigation. It is tested and achieved over 93.5% accuracy on the modeled data, 99.5% mAP score on the wearable device, and 99.5% detection of position and movement in the camera-based non-invasive system.

Maryland

Decoding the Brain: How Does the Brain Define Social Intelligence in Primates?

Nadiat Adedoyin

Baltimore Polytechnic Institute, Baltimore City, MD

Mentor: Dr. Ed Connor, Johns Hopkins University, Zanvyl Krieger Mind/Brain Institute

Whether greeting a friend with a handshake or a polite "Hello," social intelligence has defined the social structure and hierarchies amongst several primate species, ranging from humans to macaques. Interestingly, social intelligence is heavily intertwined with familiarity and memory



function in the brain. Though individuals spend their entire lives collecting social knowledge to navigate their perspective of the 3D world, there has yet to be a comprehensive analysis of the human brain through a coding scheme. Our research team has observed the social hierarchies in rhesus macaques, a closely related ancestor to humans, through an intensive video-logging video metric. I hypothesized that the social distribution across two primate groups would vary by kinship and the number of female monkeys present. So far, our observational data has refuted my hypothesis that a male primate is often the highest-ranking primate within a social group. Our results did not support that female macaque mothers with stronger parent-child relationships are more likely to be dominating or aggressive. Therefore, it may be that maternity amongst female primates does not remarkably factor into aggression or social dominance. With further research, we can learn to which extent rhesus macaque monkeys perceive animals across different levels of familiarity and how far social relations play into their memory. We hope to find a way to decode the brain's abstract neural system and better understand how social intelligence presents itself in primate social groups. This places the novel creations of sensory technology or advanced AI technology into the foreseeable future.

Decoding Circadian Gene Regulation Using a Novel Machine Learning Framework

Kelly Ji

Centennial High School, Ellicott City, MD

Mentor: Dr. Chi Dang, Johns Hopkins University

Circadian clocks are internal 24-hour rhythms that synchronize body functions with day-night cycles. At the molecular level, they consist of gene networks that control gene oscillations, governing nearly all physiological processes. Circadian rhythm disruption is increasingly linked to disease, particularly cancer, yet circadian patterns in different tissues, their regulators, and the mechanisms and effects of circadian gene disruptions remain largely unknown. To address this, I studied genes' circadian programs across healthy tissues and modeled how disruptions in clock regulators alter these rhythms. Using RNA-seq data from 64 baboon tissue-types, I identified 13,211 significantly oscillating genes (false discovery rate < 0.2) and quantified their oscillation patterns, including amplitude and peak-transcription times, revealing coordinated "wake-up" times across tissues. By integrating public RNA-seq and ChIP-seq data from ENCODE, I developed a Random Forest machine learning framework, CYFOR, to infer regulatory networks governing genes' circadian patterns, identifying 37 new circadian regulators beyond the 9 known core clock genes. Follow-up experimental studies on a CYFOR-predicted circadian regulator, MYC – a key oncogene driving 40% of cancers – revealed that it binds to similar DNA sequences as core clock gene ARNTL (p-value < 0.0001). Additionally, RNA-seq analyses in a human neuroblastoma cell line, SHEP, show that MYC overexpression disrupted rhythms of 88.5% genes oscillating in normal conditions. These data validate my computational prediction and suggest a cancer-causing mechanism where MYC disrupts normal circadian rhythms by competing with core clock genes on their DNA binding sites, demonstrating CYFOR's ability to model circadian disruption in human disease.

AI-Mediated Computational Analysis of Bispecific RNA-Based Aptamers Targeting the Transferrin Receptor of Blood Brain Barrier and EpCAM in Glioblastoma

Diya Kamalabharathy

Poolesville High School, Poolesville, MD

Mentor: Dr. Gaurav Sharma, Eigen Sciences

Glioblastoma Multiforme (GBM) is a highly malignant brain tumor originating from glial cells, characterized by aggressive proliferation, infiltration, and resistance to conventional therapies. The blood-brain barrier (BBB), which protects the brain, makes targeting GBM cells even harder



by blocking most drugs. Transferrin receptors (TfR) have shown promising results in mediating drug transport across the BBB. This study leverages machine learning, deep learning, and computational simulations to design bispecific aptamers – single-stranded nucleic acid ligands engineered for high specificity and binding affinity – that facilitate BBB penetration via TfR and subsequently target overexpressed EpCAM receptors on GBM cells. I hypothesized that drug-bound aptamers can mimic transferrin proteins, bind TfR to traverse the BBB, and deliver therapeutic agents to GBM cells. The TfR and EpCAM receptor structures were modeled using AlphaFold 3, a machine learning-based method. Four potential aptamer candidates and their mutant secondary and tertiary structures were elucidated using DNAfold and FARFAR2 software. The 3D-modeled aptamers were docked on TfR to understand the binding interactions using the HDock2.0 software and further validated using the deep learning-based method ScanNet. The number of interactions (using PLIP) and binding affinity (utilizing PDA-Pred) were computed to select the aptamers. The results depicted that aptamer hmBS04 is a promising candidate, potentially enabling dual-targeting strategies to enhance drug delivery across BBB. Virtual reality was also used to visualize the results. Finally, molecular dynamics simulations were performed to confirm that the aptamer remained bound to the receptor. These results will pave the way for designing aptamers targeting glioblastoma cells.

Designing a Light Inducible Protein Crystal

Mia Spruge

Baltimore Polytechnic Institute, Baltimore, MD

Mentor: Willow Rock, Johns Hopkins

Cells are known as the building blocks of life which also makes them the building blocks of disease. Cells degrade foreign material that could be dangerous or unnecessary on a daily basis. Organelles, known as lysosomes, are responsible for degrading this material into macromolecules that may be recycled. This is the process for most materials, however lysosomes can fail to dissolve crystals. As a result lysosomes get stressed out, and there is evidence that they leak lysosomal contents that, in turn, act as a distress signal to cells. This signal can then amplify into an inflammatory response, manifesting as chronic inflammation within tissues. Currently, it is not well understood how lysosomes tell cells they are struggling to dissolve a material. To investigate this process, I wanted to develop a protein crystal into a tool that can form on cue. Using iPak4 and FC-1, I added a photocleavable protein to disrupt the formation of the crystals. Then when the photocleavable protein is exposed to light it should break into small parts and allow the crystals to form. The end goal was to design a light inducible protein crystal that could be used to study inflammatory pathways as a model for crystal-induced damage to lysosomes. Future research could use this work as a basis or a tool for working with and understanding lysosomes and autophagy better.

Reducing Mortality Risk in Veterans: Employing Oxidative Stress Genomic Data and Patient Records to Develop a Machine Learning Model to Supplement Current Diagnostic Tools

Dhruv Veda

Centennial High School, Ellicott City, MD

Blast-Induced Traumatic Brain Injury (bTBI) presents a major risk for veterans due to its extremely rapid progression, with mild cases often advancing to severe cases with a 22% mortality rate. Current diagnostic technology lacks specificity and sensitivity, detecting only 50% of cases on the first attempt, failing to identify subtle symptoms. A long chain of communication between specialists further delays intervention, leaving veterans vulnerable to neurological deterioration.



This study developed an innovative late fusion machine learning (ML) diagnostic tool that integrates the results of genomic and clinical data ML models, presented in an Explainable AI (XAI) dashboard improving bTBI diagnosis.

Genomic research at Walter Reed Army Institute of Research examined reactive oxygen species (ROS)-related gene expression in blast-exposed ferrets using qRT-PCR, revealing significant increases in ROS-breakdown enzymes (SOD1, GPX1, CAT; $p < 0.05$) and trends in mitochondrial genes (OPA1, FIS1), supporting the viability of ROS-related genes in bTBI diagnosis.

Two ML models were developed: a PCA-optimized K-Nearest Neighbors model achieving 97% accuracy in gene expression pattern analysis, and a Random Forest classifier reaching 98% accuracy in clinical data (patient history and symptoms) analysis. A late-fusion model combines these results in an XAI dashboard offering transparency, empowering physicians to make informed decisions.

This modular framework: (1) improves sensitivity and specificity by integrating genomic and clinical data with ML, achieving up to 40% higher accuracy; (2) enhances early bTBI detection potentially saving veterans' lives; (3) provides a scalable platform for diagnosing diverse neurological conditions, extending its potential impact beyond bTBI.

Michigan

Advance Phosphor Applications: Integrating Red Phosphorus - Polypropylene Based Sealant into Electric Vehicles

Paul Garrison

Renaissance High School, Detroit, MI

The aim of this research project is to combine red phosphorus - polypropylene sealant with electric vehicle battery casings to help prevent fire from spreading in electric vehicles. This project came out of a need for increased fire safety in electric vehicles due to their increased probability to ignite in flames compared to traditional internal combustion engine vehicles. Red phosphorus is an excellent solution to this problem due to it being used in forest fires and how easily it can be implemented in polyolefins. My hypothesis was that the red phosphorus - polypropylene sealant used would be able to be used in electric vehicle battery casings to help reduce the spread of fire. Through thorough experimentation, I was able to see the effectiveness of the red phosphorus - polypropylene sealant in preventing the ignition of polyolefins. The sealant was proven to be very effective in preventing ignition in polyolefins by stopping the fire from reaching the object and producing a char layer upon reacting to oxygen. The sealant is most likely able to be effectively used in an electric vehicle battery casing to prevent fires, although in the future more testing will be required.

Decoding ASXL3: A Novel Biomarker and Treatment for Neurodevelopmental Disorders

Maya Hammoud

Detroit Country Day School, Beverly Hills, MI

Mentors: Dr. Stephanie Bielas and Ms. Emily Peirent at the University of Michigan

Teacher: Mrs. Lara McMillan

A recent study revealed that 33% of individuals with neurodevelopmental disorders (NDDs) carry ASXL3 mutations, although its function was previously unknown. To investigate, we used



CRISPR to engineer three H9 embryonic stem-cell lines with distinct genotypes: wild-type (ASXL3 +/+), heterozygous (ASXL3 +/-), and homozygous knockout (ASXL3 -/-). The successful generation of these cell lines was confirmed through PCR and DNA sequencing. Neural rosettes and organoids were derived from these lines to study growth and differentiation using imaging and RNA sequencing. ASXL3 -/- rosettes and organoids exhibited accelerated growth rates, with a higher proportion of Ki67-positive proliferative cells, indicating an expansion of neural progenitors. However, ASXL3 -/- organoids showed impaired neuronal differentiation, particularly in layer five cortical neurons, with significantly fewer BCL11B-positive cells. Differential RNA sequencing further validated increased proliferation and reduced differentiation in ASXL3 -/- cells. These findings identified ASXL3 as a neuronal stem cell gate controller, regulating the balance between proliferation and differentiation and emphasizing its essential role in brain development. ASXL3 -/- cells were also established as a novel biomarker for NDDs. The loss of layer five neurons aligns with clinical deficits in communication and fine motor skills. To address these defects, we treated ASXL3 -/- cells with fibroblast growth factor (FGF) at 10, 20, and 30 ng/ml concentrations. Treatment with 30 ng/ml FGF successfully rescued neuronal differentiation with 92% efficiency, representing the first-ever treatment for ASXL3-associated defects. These findings offer critical insights into ASXL3's role and its therapeutic potential in mitigating NDD symptoms.

MSST Transformer: A Novel Multimodal Spatial-Spectral-Temporal Transformer for Time-series Hyperspectral Imaging in Plant Growth Modeling

Michael Hua

Cranbrook Kingswood School, Bloomfield Hills, MI
Mentor Dr. Zichun Zhong, Wayne State University

Controlled environmental agriculture provides innovative methods for cultivating plants to address challenges like food security, environmental sustainability, and urban agriculture. Precision control of environmental conditions has the potential to significantly improve plant growth. Accurate modeling of the interaction between the plant and its environment is essential for implementing precision control. Hyperspectral imaging has high potential for this purpose because it can capture detailed spectral information across a wide range of wavelengths from plants. However, the higher dimensionality, larger sizes, and complex nature of hyperspectral images pose a significant challenge if used for temporal studies of plant growth. Subtle variations in plant properties and physiological changes need to be identified and correlated to provide accurate plant growth assessment. This paper introduces a novel multimodal spatial-spectral-temporal transformer designed to analyze the space, spectrum, and time domains of the hyperspectral images. The transformer is trained on hyperspectral images of growing plants, corresponding light treatments, and final biomass outcomes to learn a statistical model which captures the intrinsic relationship between plant growth patterns and environmental factors. Specifically, the spatial-spectral transformer divides the input image into 3D hyperspectral patches and utilizes a novel 3D-aware positional encoding and self-attention mechanisms to capture global dependencies among patches. Subsequently, the temporal transformer models time-variant spatial-spectral representations and their long-range relationships. Finally, the multimodal cross-attention mechanism explores the interaction between environmental features and spatial-spectral-temporal representations from hyperspectral plant images, resulting in an accurate plant growth model. Comprehensive experiments demonstrate the effectiveness and superiority of the proposed network.



Detecting Polyps in the Colon Using Machine Learning

Diya Ramakrishnan

Saginaw Arts and Sciences Academy, Saginaw, MI

Teacher: Ms. Clara Wagner from Saginaw Arts and Sciences Academy

Polyps, a small cluster of cells that grow on the lining of the colon, are becoming more common, with over 2.4 billion people who have polyps. Polyps are linked with conditions like cancer and inflammatory bowel diseases, which both have severe effects if not detected during their early stages. With over 30.9% of polyps being missed during colonoscopies, being able to detect these polyps is crucial. The goal of this project was to use a Convolutional Neural Network (CNN) and a YOLO model to detect, localize and classify polyps. The CNN classifies the images as having a polyp or not, while the YOLO detects its location and if it is an adenomatous or hyperplastic polyp (the two major classes of polyps).

In the experiment, four different CNN models were tested. Each model had different hyperparameters. It was determined that Model 1 had the highest validation accuracy while Models 2 and 3 experienced overfitting. During the image classification tests, Model 1 had a 92% accuracy, Model 0 had a 82% accuracy, and Models 2 and 3 both had an accuracy of 42%. Two YOLO models were tested: a YOLOv5 and a YOLOv7. The YOLOv5 had the highest mean average precision (mAP) of 99.3%, recall of 98.1%, and precision of 98%. Model 1 and YOLOv5 were converted into a website called PolypDetect, which has life saving consequences, as it can detect, localize, and classify polyps from both images and videos, allowing for early treatment.

Mississippi

Screening for Genetic Markers Captured in DNA to Determine Scrapie Resistance in Ovis aries

Jaden Claire Everett

Starkville High School, Starkville, MS

Teacher: Sarah Langford, Starkville High School

Scrapie is a neurological disease that is fatal to sheep. Since I raise and show sheep in 4-H, I wanted to make sure that my flock was resistant to scrapie and that when I am seeking potential sires/rams to breed my dams/ewes to that I am not infecting my flock, or breeding to a ram that could potentially pass the scrapie gene onto an offspring. Therefore, the problem being addressed in my experiment is Screening for Genetic Markers Captured in DNA to Determine Resistance in Ovis aries. My number one goal is managing a flock that is genetically most resistant to scrapie and/or that could need careful selection when used for breeding. To complete this goal, I collected DNA samples from each of my sheep and sent the samples off to Gene Check, Inc. for genotyping. The samples were taken using a Datamar Collector and Collection Tags. The results were emailed to me, and I was able to determine that one of my ewes in fact is susceptible to scrapie based on her Codon 171 results. In conclusion, I now have a decision to make regarding this one ewe. I am not going to rush to decide. I do plan to continue to collect DNA samples on all new sheep that enter my flock, so that I can make sure that I am accomplishing my main goal.



Authorship Verification for Academic Dishonesty in the Era of AI

Jun Jang

Oxford High School, Oxford, MS

The rise of artificial intelligence (AI) has both positive and negative effects on student performance in the classroom. While AI offers various learning benefits, studies suggest it can hinder creativity and critical thinking skills. One area where AI may do more harm than good is academic writing. This paper presents an authorship verification (AV) software designed to assist teachers in detecting writing dishonesty, a common form of academic dishonesty. Our proposed AV system extracts a novel set of linguistic and structural features including vocabulary usage, sentence structure variation, readability, and predictability from texts to distinguish an author's unique writing style. These features are then used to train machine learning (ML) classification models to determine authorship similarity. Using the Reuters dataset and real high school student essays, our proposed AV system demonstrates superior detection accuracy in comparison to the state-of-the-art AVs in the literature. Our study highlights the importance of feature development, preprocessing, robust feature engineering, and binary classification ML models as they significantly impact authorship verification performance.

Preventing Traffic Accidents Involving Right-Turn-On-Red at Intersections with Edge AI

Yoon Jang

Oxford High School, Oxford, MS

Mentor: Dr. Bo Wang, The University of Mississippi

Fatal accidents involving right-turning vehicles on red lights with pedestrians crossing at intersections emphasizes the need for an accurate and reliable way of alerting drivers and pedestrians. Recent advancements in AI-powered computer vision technology on edge devices offer a great opportunity to solve this public road safety problem by providing superior accuracy and speed compared to previously existing traditional methods. In this paper, we present a collision detection system designed to prevent these traffic accidents by utilizing the latest AI object detection technology. Our novel collision detection algorithm utilizes the nearest distance calculation between vehicles and pedestrians detected from the latest AI neural network as well as motion vectors that tracks past movements and estimates future movements. The proposed solution is prototyped on the latest edge AI computing device, the NVIDIA Jetson Orin Nano development board, with real-world deployment in mind. Our experiments show that our system can predict potential collisions accurately if objects are detected by the AI model we used. This research demonstrates that AI-powered computer vision technology can help reduce accidents at intersections and improve road safety.

Decoding Influenza: Analyzing Drug Resistance Patterns in Neuraminidase Genes to Combat Antiviral Ineffectiveness

Ananya Mantri

Northeast Lauderdale High School, Meridian, MS

Sponsor: Mrs. Amy Gonzalez, NEHS Science Fair Coordinator

The increasing prevalence of antiviral drug resistance in influenza viruses poses a significant threat to public health. Neuraminidase inhibitors, such as Oseltamivir, are widely used to treat influenza, but their effectiveness has diminished due to resistance-conferring mutations in the neuraminidase (NA) gene. This study aims to identify key mutations linked to resistance and analyze their impact on antiviral sensitivity. It was hypothesized that influenza viruses exhibit distinct drug resistance patterns, with specific NA mutations being more prevalent in resistant strains.



Influenza A (H1N1, H3N2) and influenza B virus strains from the 2020–2021 and 2022–2023 seasons were selected for analysis using the NCBI GenBank database. Neuraminidase protein sequences were aligned with reference sequences using Clustal Omega to detect resistance-associated mutations. Mutations such as H275Y and D197N, previously linked to reduced susceptibility to Oseltamivir, were examined. Resistance levels were categorized based on IC50 values obtained from literature reviews.

Higher IC50 values, indicating reduced susceptibility to neuraminidase inhibitors, were correlated with specific mutations. The H275Y mutation, in particular, was associated with significant Oseltamivir resistance. The findings support the hypothesis that certain mutations have a major impact on antiviral susceptibility and occur more frequently in resistant strains.

This study highlights the importance of continuous surveillance of resistance-conferring mutations to inform antiviral treatment strategies and public health initiatives. Understanding resistance patterns can aid in the development of more effective antiviral drugs and vaccines, ultimately improving the management of future influenza outbreaks.

Multi-Dimensional County-Level Risk Factors Associated with Lung Cancer Incidence in the United States: Generalized Linear Models and Machine Learning

Harrison Shao

Mississippi School for Mathematics and Science, Columbus, MS

Sponsor: Dr. Jason Palagi

Numerous studies examined how individuals' health behaviors affected lung cancer incidence and showed racial and regional inequalities in the United States. My study drew county-level risk factors to predict age-adjusted lung cancer incidence rates. In a national sample of 2,469 counties, I used risk-adjusted Generalized Linear Models (GLMs) and Bootstrapping Machine Learning methods to test the county-level associations between healthcare access, social vulnerability, smoking rates, environmental quality, and lung cancer incidence rates. I had the following findings: (1) A county with the highest percentage of primary care physicians was associated with a 6% lower rate of incident lung cancer (Odds Ratio=0.94, $p<0.05$); (2) A county with the highest smoking rate was associated with a 51% higher rate of incident lung cancer (Odds Ratio=1.51, $p<0.05$); (3) A county with the poorest environmental quality had a 12% higher rate of lung cancer incidence (Odds Ratio=1.12, $p=0.05$); (4) A county with the higher percentage of black residents (Quartile 2 and 3 vs Quartile 1) was associated with at least 5% higher rate of lung cancer (Odds Ratio=1.05, $p<0.01$). My study demonstrates the statistically significant effects of multidimensional county-level risk factors on lung cancer incidence, advancing existing literature that focused predominantly on individual factors. This study suggests that more resources should be distributed to counties with unfavorable healthcare access and environmental quality as well as those with high levels of social vulnerability, especially in rural areas. Reducing smoking rates will also help decrease the occurrence of lung cancer.



Missouri

Harnessing the Power of Gut Microbiota Isolated from *Zophobas morio* for In Vitro Biodegradation of Expanded Polystyrene Foam

Zebediah Bruna

Lebanon High School, Lebanon, MO

Teacher: Mr. Ryne Emerick, Lebanon High School

Plastic pollution is a major issue in our modern world, and expanded polystyrene foam is one of the most common plastics found within landfills and pollution in the environment. As there is no affordable method of recycling this plastic currently, a way that may prove fruitful in the future is the method of biodegradation. *Zophobas morio* survives on a diet exclusively composed of polystyrene foam, suggesting that its gut microbes can break down the material into nutritionally valuable carbon compounds. This research is being done in order to examine the EPS biodegradation capabilities of gut microbes found within the gut of *Z. morio*. To do this, microbes will be isolated from the gut of *Z. morio* in both anaerobic and aerobic conditions. It is hypothesized that the anaerobic microbes found within the gut of *Z. morio* will have greater EPS biodegradation capabilities than microbes isolated in anaerobic conditions, due to the use of largely unstudied anaerobic digestion pathways. Microbes will be cultured in conditions where the sole carbon source is EPS, and 16s rRNA sequencing will be used to identify isolated microbes. Growth rates of bacteria were recorded to assess their capability to biodegrade EPS. Aerobes and anaerobes had no statistically significant difference in growth rates between them. Comparable rates between the two ultimately shows the feasibility of anaerobic tanks as a feasible method of biodegrading EPS.

Fighting the Brain Injury Crisis: A Protective & Affordable Helmet

Vihaan Choudhary

Lindbergh Senior High School, St. Louis, MO

Mentors: Dr. Claudia Preston, AIM Online ScienceCoach; Dr. Lisa MacFadden, University of South Dakota

Traumatic brain injuries (TBIs), a leading cause of death/disability, afflict >55 million people worldwide; >90% of TBI-related deaths occur by road traffic accidents, the primary cause being lack of high-quality, affordable helmets. This study hypothesizes that shear-thickening fluid (STF) is more effective in impact protection for helmets than currently used materials. Cheaper and readily-available materials (i.e., cornstarch/water) were used to create an STF called Oobleck, which was vacuum-/heat-sealed in a vacuum-sealable bag and Mylar bag. Experiments were conducted using bike and football helmets on a standardized NOCSAE headform, using vinyl nitrile (VN) foam as control; Severity Index (SI) and G-force (g) were measured after dropping helmet/headform on anvil from 3 feet (average height of fall from bike). Force transmission (lbf) was also used to compare the STF and VN (weight dropped on layer/foam from increasing heights). SI/g values for bike helmet were statistically significant for crown, rear, and side drops ($p < 0.01$). SI/g values for football helmet were significant for crown/rear and crown/side drops, respectively ($p < 0.05$). Lbf values were significant for drops >12 inches ($p < 0.01$). Overall, the STF layer outperformed the VN foam in SI, g, and lbf, indicating that the STF offers better impact protection in helmets compared to the widely used VN. Next steps involve testing STF's effectiveness in rotational force absorption and defining the layer's optimal thickness/configuration. Successful completion of this project will facilitate development of a protective, affordable headgear technology.



Modeling in Danio Rerio How Hyperactivity is Affected by Different Wavelengths of Light Through a Range of Ages

Natalie Kiehl

Holt High School, Wentzville, MO

The increased use of technology has led to an increase in blue light exposure to children across the country. Studies have shown blue light to have negative effects on human circadian rhythms. The goal of this project is to determine the effect of blue light on individuals as a function of age. Zebrafish have been chosen as the model organism in this experiment. Behavior after exposure to various light wavelengths was studied on zebrafish ranging from late larval through late juvenile stage. Fish motion was tracked and analyzed using video analysis software after 10 minutes of exposure to either white or blue light. Time spent swimming at speeds less than 25% of the average speed, number of direction changes, percent of time spent in the center, and total distance swam were assessed. Movement data for fish aged 30, 42, and 51 DPF has been collected and initial results indicated that the blue light results fluctuated more between individual fish compared to the white light fish. The other conclusion that can be drawn from both observation as well as data analysis is that as the fish age, they tend to swim a further total distance at a faster speed with less time spent not moving. Said results neither confirmed nor denied the hypothesis for this experiment, however, the data shows several behavioral factors that can be further analyzed and may lead to more significant implications.

The Impact of Doxorubicin on 4-HNE Aggresome Processing in Cardiac Cells: Analyzing Autophagy Flux

Varsha Manikandan

Kirksville Senior High School, Kirksville, MO

Mentor: Dr. Sumitra Miriyala, A.T. Still University

Doctors use doxorubicin as a chemotherapy treatment for multiple cancer types. Doxorubicin shows strong cancer treatment results, but its side effect of heart damage remains its most significant challenge. Scientists know ROS damages cell parts when doxorubicin produces these reactive oxygen species. ROS attacks lipids, producing 4-hydroxynonenal (4-HNE), which forms covalent bonds with proteins. When proteins undergo harmful changes, the cell works to contain these misfolded proteins in aggresome structures it tries to degrade. Cells use autophagy to break down damaged parts and keep themselves healthy. The heart cells known as cardiomyocytes need perfect autophagy to handle stress from doxorubicin treatment. This research studies the capacity of MnTnBuOE-2-PyP5+ (MnP, also known as BMX-001) to break down damaged aggresomes in H9c2 cardiomyocytes through its superoxide dismutase (SOD) mimetic action. BMX-001 acts like superoxide dismutase to help cells break down ROS-caused aggresomes and reduce their harmful effects. We used an in vitro model to test the doxorubicin effect in H9c2 cardiomyocytes. After 24 hours of doxorubicin exposure, cell viability was assessed using the Evans Blue exclusion method. Two concentrations of BMX-001 were tested, with 10 μ M and 20 μ M selected for optimal cardioprotection. The treatment's impact on intracellular superoxide levels was quantified using HPLC post-DHE treatment. This research shows BMX-001 can lower oxidative stress indicators in H9c2 cells under Doxorubicin treatment and demonstrates its therapeutic power in heart-related cancer treatments. BMX-001 acts as a SOD2 mimetic to protect cardiomyocytes and help patients with heart conditions caused by chemotherapy-induced oxidative stress.



Identification of Potential Inhibitors Targeting DNA Replication of Mycobacterium Tuberculosis

Satvik Rachagani

Rockbridge High School, Columbia, MO

Mentor: Kamal Singh, Faculty, PhD, Banaras Hindu University

Bacterial antimicrobial resistance (AMR) represents a major public health threat, with projections estimating ten million deaths by 2050 due to AMR. Contributing factors to AMR include the misuse and overuse of antimicrobials in humans, animals, and the environment, along with the global spread of multidrug-resistant (MDR) bacteria and resistance genes across these areas. This crisis has driven research into alternative treatments and better antimicrobial stewardship to combat MDR pathogens. Among the challenges is the rise of drug-resistant *Mycobacterium tuberculosis* (Mtb), which necessitates the continuous development of new drugs effective against both multi-drug-resistant (MDR) and extensively drug-resistant (XDR) Mtb strains. Recent research has highlighted nargenicin, a natural product, for its ability to inhibit Mtb growth by targeting the bacterial DNA replication polymerase DnaE1. Nargenicin binds to the active site of DnaE1 in the presence of a DNA substrate. This discovery has paved the way for drug discovery efforts focused on Mtb DnaE1. Using an in-house developed platform, we have identified ten compounds that interact with the nargenicin binding pocket. These 'hit' compounds are currently undergoing structure-activity relationship (SAR) studies and medicinal chemistry modifications to develop lead compounds targeting DnaE1.

New England Northern

AI on Edge: Novel Post-Training Quantization for Education Applications

Eric Buehler

Home School, Madison, NH

Teacher: YuChing Buehler, Home School

Could a personalized, portable AI tutor transform education and improve outcomes for students in disadvantaged communities? Advancements in open-source large language models (LLMs), particularly multimodal models that can understand images and text, enable AI-driven learning by giving students personalized feedback while addressing privacy and sustainability concerns. However, running these models on consumer edge devices like a cell phone remains cost-prohibitive. I hypothesize that AI can be made more efficient for use on a phone through an improved algorithm that decomposes connection strengths of a neural network into two parts, one within a range that can be exploited to reduce memory footprint. This would allow me to fit a powerful AI model onto a phone while retaining high accuracy. My novel post-training quantization method outperforms other quantization techniques, achieving up to 3.27x higher speed, superior accuracy, and at least the same level of size reduction. It compresses a cutting-edge 8-billion-parameter model from 16 GB to 8.16 GB RAM, reducing its size by 49%. Integrated into my custom open-source inference engine written in Rust called *mistral.rs*, this approach powers *Edge(u)cation*, an AI tutor app I created for mobile devices. To validate its impact, I then deployed *Edge(u)cation* in several sample settings including math and engineering bridge structure analysis experiments through real-time, AI-driven feedback. In conclusion, this work demonstrates a scalable, cost-effective solution for personalized learning, fostering STEM engagement in under-resourced communities, enabling usage offline or off-grid. I published all codes and models in open-source for anyone to use and build on: <https://github.com/EricLBuehler/edge-u-cation>.



Modulation of TLR2-Mediated Innate Immunity Mitigates Inflammatory Pathology in Alzheimer's Disease

Ethan Liu

Phillips Exeter Academy, Exeter, NH

Alzheimer's disease (AD) is an irreversible neurodegenerative condition marked by the progressive loss of memory and cognitive function. The risk for AD increases exponentially with age. This study aims to explore the molecular mechanisms that differentiate healthy aging and AD-associated aging. In the experiments, I combined single-cell transcriptomic analyses of multiple AD patient datasets with drug validation using the following AD experimental models: transgenic strains of the nematode worm *Caenorhabditis elegans* (GMC101 strain expressing amyloid- β protein in body wall cells and N2 WT control strain) and mouse cortical neuron cultures. From bioinformatic analyses, I discovered several differentially expressed genes (e.g. TLR2, HSD11B2, CXCR4) that potentially drive the pathogenesis of AD. I examined these genes through several *in vivo* and *in vitro* experimental methods. Immunohistochemical staining and brightfield imaging of neurons treated with C29, a potent TLR2 antagonist, revealed increased cell survival and more neural processes compared to controls. Furthermore, *C. elegans* lifespan and movement assays demonstrated that C29 significantly boosted the lifespan and motility of AD worm models. Through comprehensive bioinformatic analysis and experimentation, I conclude that TLR2 antagonist C29 may be a novel disease-modifying drug candidate for AD. This study provides valuable insights into the pathogenic nature of upregulated TLR2 in AD. These conclusions will support future research and developments of disease-modifying drugs for AD, promote healthy aging, and improve healthspan and lifespan.

Improving the Effectivity of Nitrate Removal in Biosand Filters Using *N. oculata*

Sofie Rueter

Bangor High School, Bangor, ME

Teacher: Dr. Barbara Stewart, Bangor High School

Biosand filters are an effective way for rural or less-developed communities to purify water from local water sources. However, limited research has been done on how the addition of microorganisms, specifically the microalgae *Nannochloropsis oculata*, into the biolayer could improve filtration efficiency. In this project, *N. oculata* was introduced into the biolayer of a biosand filter constructed out of recycled and easily accessible materials; it was hypothesized that introducing of a new species of microalgae to the biolayer would ameliorate filtration efficiency, specifically of nitrates, from local source water. Water collected from the Penjajawoc Stream was treated with an altered filter (with *N. oculata*) and a control filter (without *N. oculata*). Nitrate concentrations pre- and post-treatment were measured; *N. oculata* cell density was measured over time. Results showed that the altered filter consistently reduced nitrate levels more effectively than the control, with an overall 60% reduction in nitrate concentration. This difference was found to be statistically significant ($n = 25$, $p < 0.01$). Moreover, evidence suggested that the population of *N. oculata* in the biolayer remained stable over time, suggesting sustainable filtration efficiency. Notably, the altered filter reached stability more rapidly than traditional biosand filters, which typically take 30 days to stabilize. Overall, these findings suggest that *N. oculata* augments nitrate removal in biosand filters, offering a more sustainable and affordable solution for improved water quality. This research is especially relevant as human populations grow and access to safe drinking water becomes increasingly critical in rural or developing areas.



Low Levels of Bioaccumulated Mercury in Lobster (*Homarus Americanus*) From the Gulf of Maine Are Elevated During the Early Fishing Season

Dan Stoicov

Falmouth High School, Falmouth, ME

Mentor: Andre van Wijnen, University of Vermont

Mercury (Hg) pollutes marine ecosystems and concentrates in benthic species. This ecological case study investigated the temporal accumulation of Hg in American lobster (*Homarus americanus*) as a bottom-dwelling species in coastal waters (Casco Bay, Maine, USA). We analyzed total Hg levels in legal-sized lobsters (carapace length: 8.255 - 12.5 cm; n=34) collected during the early (May-July 1st) or late (July 15th-October) recreational harvest seasons. Morphometric data show that individual body sizes correlate with individual body weights ($R^2=0.76$; $p<0.001$) and average body sizes were similar in early and late seasons. The average chelipod (crushing claw) size was ~7% larger in male lobsters ($p<0.02$) reflecting sexual dimorphism. Hg levels in select tissues from boiled lobsters were analyzed by atomic absorption spectroscopy. Hg in ambient water was undetectable indicating that Hg in tissues reflects bioaccumulation. Hg content correlated with the sizes (cm) and weights (g) of carapace (body), chelipod and hepatopancreas (tomalley) in male and female lobsters. The total Hg levels in most tissues examined are safe and acceptable for human consumption (<0.2 ppm). Compared to late season lobsters, early season lobsters have significantly more Hg in tail muscle (~55% increase; 0.130 ppm vs 0.084 ppm; $p<0.05$) and tomalley tissue (~29% increase; 0.099 ppm vs 0.077 ppm; $p<0.05$). These findings indicate that seasonal factors modulate Hg content in this coastal habitat (e.g., spring river run-off, lobster migration). The observed seasonal fluctuations in the Hg levels of lobsters may inform other studies and mitigation strategies for pollution patterns in coastal marine ecosystems.

Historical Trauma in Displaced Palestinians Outside of Israel: A Generational Comparative Investigation

Saladin Rocky Wise

Orono High School, Orono, ME

Teacher: Katie Quirk

This study examined the levels of Historical Loss Symptoms (HLS) in different generations of displaced Palestinians outside of Israel. I hypothesized that the levels of Historical Loss would dilute in younger generations born further from the Nakba, the mass displacement of Palestinians in the Arab-Israeli War of 1948. Using snowball sampling, I gathered 142 participants from 11 different countries. The participants fell into one of three self-identified groups as measured by their generational distance from the Nakba: second-generation (47), third-generation (62), and fourth-generation (33). Using a two-part HLS survey, adapted from one used in previous peer-reviewed studies, I tested for the frequency of perceived losses and for participants' emotional responses to the perceived losses. HLS levels were prominent across all generations, with consistent scores on perceived losses and emotional responses. An analysis of variance (ANOVA) showed no significant difference in levels of HLS across generations (p-value of 0.98 for perceived losses, and p-value of 0.57 for emotional responses to perceived loss). Furthermore, results indicated that HLS is high amongst the displaced Palestinians outside of Israel, even relative to measurements of other oppressed populations, including Iraqi Kurds and Native Americans. The three generations in comparison to one another don't point to any notable differences, suggesting that historical trauma is not a problem that has gone away with time for this population.



New England Southern

A Self-Regulating Gene Therapy Vector for Treating Rett Syndrome

Yifan Ding

Boston Latin School, Boston, MA

Mentor: Zhenghui Li

Rett syndrome is a devastating neurodevelopmental disorder caused by loss-of-function mutations in the MeCP2 gene. Gene therapy represents one of the most promising strategies for treating or potentially curing this genetic disease. However, a key challenge in developing an effective gene replacement therapy for Rett syndrome is achieving sufficient MeCP2 expression in affected cells without risking harmful overexpression. The aim of my study is to engineer a gene self-regulation system that maintains proper MeCP2 expression levels necessary for therapeutic benefit, while avoiding the detrimental effects associated with MeCP2 overexpression. Building on my previous research presented at JSHS, I introduce a novel gene self-regulation system, "TREAD-Dimmer", which leverages mechanisms of termination readthrough of the stop codon UGA and Cre-mediated recombination. In the TREAD-Dimmer system, high expression of the target gene triggers increased readthrough of a stop codon-containing sequence, leading to the translation of Cre recombinase fused downstream of the target gene. This results in Cre-mediated DNA recombination and self-deletion of the target gene, effectively downregulating its expression. Through cell culture experiments, I validated that TREAD-Dimmer can be applied to self-regulating gene therapy vectors, preventing overexpression of both green fluorescent protein and human MeCP2. Our ongoing collaborative efforts seek to further translate the TREAD-Dimmer system and its associated MeCP2 gene therapy vector into clinical applications. In conclusion, TREAD-Dimmer offers a promising solution to prevent overexpression in gene therapy, including MeCP2 gene replacement therapy for Rett syndrome, potentially improving therapeutic outcomes and minimizing risks associated with gene therapy treatments.

Design of a Tri-Star Wheel Mechanism with High Obstacle Clearance

Congyi Lucas Jiang

St. Mark's School, Southborough, MA

Sponsor: Hong Jiang

This paper explores the development and application of a tri-star wheel design for urban search and rescue (USAR) robots, addressing the critical need for a wheel mechanism able to navigate complex terrains as well as flat surfaces. While traditional wheels have only one functionality, being its excellent ability to transport objects across flat surfaces, the tri-star wheel features a second functionality being its exceptional ability to overcome vertical obstacles. It holds a special geometry that allows the wheel to pivot at a lower point compared to the conventional wheel and reduce interference during the process simultaneously. This study includes a theoretical analysis of the tri-star wheel's mechanics and mathematical modeling to optimize the wheel's parameters. Using this model, I built a prototype robot with tri-star wheels of $d=120\text{mm}$ and $r=47.5\text{mm}$, which the model predicts can overcome a vertical obstacle of maximum 203mm. A SolidWorks motion simulation was performed, followed by experimentation using the actual robot to evaluate the true performance of the tri-star wheel in overcoming obstacles. The results from the simulation and experiment were fairly consistent with the mathematical model: I found that the star wheel can overcome vertical obstacles over 67% higher than what regular wheels can, around 38% higher in obstacles less than 90° , and 14% in obstacles greater than 90° . Despite being smaller than a regular wheel, my design of the star wheel is also able to sustain heavy payloads of up to 50kg, on par with regular wheels.



Empowering Low-Resource Settings with RetinAI: An AI System with Wearable Headset and Retinal Imaging for Eye Tumor Home-Screening

Ethan Yan

Groton School, Groton, MA

Mentor: Dr. Shiqi Ling, C-MER Dennis Lam Eye Hospital

Early diagnosis of retinoblastoma (RB) in the current clinical practice remains challenging due to the lack of access to timely and accurate eye examinations which is essential as late stages of RB often lead to enucleation and blindness. To address this issue, this research develops RetinAI, the first low-cost wearable headset and retinal camera with artificial intelligence systems for early detection of RB. RetinAI consists of two components, an extraocular detection device coupled with a YOLOv11 deep learning model to detect the early sign of RB, leukocoria, and an internal retinal image system powered by ResNet-50 or YOLOv11 to detect retinal tumors. The hardware includes a 3D printed headset and lens/camera connector, Pi Camera 3, infrared/white-LED light, LCD screen, 20D lens, and Raspberry Pi 5. For leukocoria detection, color analysis of leukocoria showed they had different Value, Hue, and Saturation from normal pupils. YOLOv11 model was developed and showed a high performance of 98% mAP, and can detect leukocoria as small as 1 mm in diameter using the RetinAI headset. For RB retinal tumor detection, ResNet50 and YOLOv11 were developed and achieved 97% accuracy and 96% mAP respectively. Clinically, using RetinAI on retinoblastoma patients demonstrated that RetinAI can detect retinoblastoma tumor. RetinAI is the first low-cost system that can not only detect eye tumors from external pupil but also from retina without any pupil dilation medication. RetinAI can significantly improve RB early detection and be used at home or in small clinics without eye specialists, especially in underserved communities.

Heavy Metal Analysis of Lichen at a Massachusetts Superfund Site Reveals Previously Overlooked Contamination

Yuxuan Zhang

Boston Latin School, Boston, MA

Mentor: Susan Will-Wolf, University of Wisconsin–Madison, Madison, USA

Heavy metals are toxic pollutants that persist in ecosystems and bioaccumulate, causing chronic health issues such as neurological damage and cardiovascular diseases. Many of these metals are byproducts of industrial activities. Since the 1630s, industries along Lower Neponset River in Eastern Massachusetts released heavy metals into the environment of this now EPA Superfund. Despite cleanup programs initiated since 2023, much heavy metal contamination from centuries of industrial activity remains. To highlight this, we leveraged *Flavoparmelia caperata* (L.) Hale, an epiphytic lichen and cost-effective bioindicator, to assess heavy metal pollution at the site. We collected 88 natural lichen thalli and 25 soil samples from the Superfund, along with 3 lichen controls from MA suburban areas as local baseline. Using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), we measured concentrations of 19 trace metals in lichen and soil samples. Lichen tissue exhibited significantly elevated levels of Al, Ba, Cr, Cu, Fe, Mg, Mn, Ni, Pb, V, Zn ($p < 0.01$), with particularly severe Pb contamination. Soils exhibited mostly Pb contamination. Enrichment factor analysis reveal that *F. caperata* is a more effective bioaccumulator for monitoring air quality and modern environmental contamination than soil. Spearman rank correlation analysis further suggest distinct distribution patterns within site and different pollution sources for lichen and soil contamination. We conclude that lichens serve as a modern air pollution indicator, while soils reflect long-term, localized contamination. Given that current remediation efforts focus on polychlorinated biphenyls (PCBs), we recommend a revision of strategies to address heavy metals and its associated health risks.



Li-ion Battery Health Monitoring Using Vibration Analysis

Ethan Zhou

Massachusetts Academy of Math and Science, Worcester, MA

Mentors: Yujie Xi and Professor Zhu Mao, Department of Mechanical and Materials Engineering, Worcester Polytechnic Institute, Worcester, MA

With the growing demand for lithium-ion batteries (LIBs) in electric vehicles and energy storage, ensuring battery safety is critical. Conventional LIB monitoring relies on voltage, current, and temperature but is not capable of providing early warnings of battery abuses that make the LIBs more prone to thermal runaway. This study hypothesizes that vibration signals generated during LIB operations can distinguish different battery states.

This study explores vibration-based health monitoring of LIBs. Sensors placed on the surface of LIB cells recorded vibration signals (0–23 kHz) during normal operation and abusive conditions (overcharging/over-discharging). Fast Fourier Transform (FFT) and Gaussian smoothing were used to preprocess the data. Advanced data processing techniques, including cosine similarity and t-distributed stochastic neighbor embedding (t-SNE), were employed for data classification and assessing battery deviations from normal health conditions.

When overcharged, LIB cells exhibited changes in vibration signals at key voltages, corresponding to different material structures at the cathode. Over-discharging revealed no significant vibration changes initially, but subsequent recharging showed distinct stages in vibration signals, indicating potential alterations in electrode materials. Vibration signals from LIBs in healthy, previously over-discharged, and previously overcharged states showed three distinct clusters representing their health states. The distinguishable battery states observed through vibration measurements are consistent with previous X-ray diffraction studies reported in the literature.

These findings demonstrate for the first time that vibration signals effectively detect subtle structural changes in LIBs, complementing conventional monitoring. This low-cost, nonintrusive approach provides early indicators of battery degradation, adding a new dimension to battery health diagnostics.

New Jersey Northern

Reducing Per-and Polyfluoroalkyl Substances (PFAS) Water Contamination with Mycorrhizal Hydroponics Plants and Constructed Wetlands

Neel Ahuja

Millburn High School, Millburn, NJ

Teacher: Mr. Christopher Cook

Per- and polyfluoroalkyl substances (PFAS) "forever chemicals" are common carcinogenic water pollutants, causing 382,000 global deaths annually. Over 600,000 military personnel are annually exposed to unsafe PFAS levels due to aqueous film-forming foam (AFFF), a PFAS-containing substance used by the military. Current methods to purify PFAS-contaminated water cost millions of dollars and require existing infrastructure, making them inaccessible in low-income and rural areas without industrial treatment facilities. Hydroponics plants colonized by beneficial mycorrhizal fungi present an affordable and sustainable solution to purifying PFAS-contaminated water. In this study, mycorrhizal-inoculated basil and lettuce plants were cultivated in controlled



hydroponics systems. Root samples were stained and analyzed under a light microscope to confirm mycorrhizal presence. PFAS was added to the systems and an LC/QQQ-MS instrument was used to measure the reduction in PFAS concentrations over 72 hours. Results showed that mycorrhizal plants removed 71.1% of PFAS compared to 59.9% by non-mycorrhizal plants, and a t-test (p -value=0.00367) proved statistical significance. Further analysis revealed a direct relationship between plant root length and PFAS purification, indicating the suitability of species with naturally longer roots for phytoremediation. After providing this proof-of-concept of mycorrhizal plants reducing PFAS contamination in a controlled environment, a constructed wetland was designed and implemented at a local pond. Results revealed that mycorrhizal elephant ear plants removed 21.3% of PFAS over 28 days. This study demonstrates the effectiveness of constructed wetlands with mycorrhizal plants as an inexpensive and sustainable PFAS purification system for real-world applications.

Mathematical Modeling of T-Cell Mediated Oncolytic Virotherapy for Glioblastoma Treatment

Daniel Han

Millburn High School, Millburn, NJ

Sponsor: Christopher Cook

Oncolytic virotherapy (OV) is a form of immunotherapy that uses specific viruses to prevent cancer cell proliferation. Specifically, the Zika virus has shown promise in combating glioblastoma, and they have shown to work with various aspects of the immune response such as T-Cells to eliminate not only glioblastoma cells, but also cancer stem cells. Mathematical models have also shown promise in simulating how these factors interact with one another. In this paper, we aim to answer the following research question: what are the optimal conditions in which the Zika virus population and T-Cell population work together to make the virotherapy as successful as possible? We hypothesized that intermediate values surrounding how efficiently Zika viral particles and T-Cells replenish are necessary for close to successful therapy. Ultimately, by using our ODE (Ordinary Differential Equations) mathematical model, our hypothesis was confirmed; both our analytical and numerical results are in agreement and demonstrate that a lack of either factor is detrimental towards virotherapy. There exists critical values where there are major changes in population dynamics as well as the stability of how the cancer stem cells proliferate or decrease as a result of the Zika virus and/or T-Cells.

Unlocking Neuroprotection: How Chebulinic Acid Targets Protein Biomarkers and Lipid Imbalance in Alzheimer's Disease

Kevin Jin

Delbarton School, Morristown, NJ

Mentor: Wei Zhu, SCI Research Institute

Alzheimer's disease (AD), a neurodegenerative disorder causing cognitive deterioration, remains a leading cause of death. Previous research has looked into the effects of amyloid-beta ($A\beta$) and genetic and bacterial risk factors - specifically apolipoprotein E4 (ApoE4) and lipopolysaccharide (LPS) - as factors behind lipid droplet (LD) formation in AD. This study aims to determine the specific effects of these molecules on lipid dysregulation in AD. It also investigates the efficacy of chebulinic acid (CA), a natural plant-based chemical, as potential treatment for AD.

Molecular docking revealed strong binding affinities for $A\beta$ with the acyl-CoA synthetase long-chain (ACSL) family, suggesting ACSL's role in LD formation. CA also demonstrated properties similar to Triacsin C, an inhibitor of the ACSLs, indicating its potential to prevent LD production. CA reduced cell adhesion and therefore neuroinflammation caused by $A\beta$ and LPS. Both AB and



LPS caused an imbalance in LD formation, harming storage cells and structures. By reducing lipid production and LD formation, CA mitigated the harmful lipid dysregulation caused by A β and LPS.

A β and LPS further disrupted ApoE balance, differentially promoting harmful ApoE4 expression while decreasing production of more protective ApoE alleles. CA prevented the upregulation of ApoE4. In a *Drosophila* model, both A β and ApoE4 impaired locomotion, demonstrating further lipid dysfunction, while CA consistently improved movement, indicating broad therapeutic benefits.

Overall, this study clarifies the specific roles of A β , LPS, and ApoE4 in AD lipid dysregulation and highlights CA as a promising candidate for AD treatment, counteracting multiple disease-promoting factors.

Investigating Hand Dexterity Improvement in Individuals with Traumatic Brain Injury using Targeted Neuromodulation Combined with Music-based Exergaming: A double-blinded Randomized Controlled Trial Study

Ari Kestenbaum

Livingston High School, Livingston, NJ

Mentor: Dr. Vikram Shenoy, Kessler Foundation

From 2000-2017, more than 375,000 military members have been diagnosed with traumatic brain injury (TBI), according to the Department of Defense. TBI is a leading cause of motor impairment with nearly 50% of TBI patients suffering with upper-extremity motor function. Due to a need for more personalized rehabilitative treatments, the goal of this study was to evaluate a combined approach of 1) targeted High-Definition Transcranial Direct Current Stimulation (HD-tDCS), a non-invasive brain stimulation that delivers currents to excite and reconnect neurons, and 2) MusicGlove, an FDA-approved wearable glove that requires patients to make various finger movements in accordance with music notes appearing on a screen. It was hypothesized that hand dexterity can be improved in individuals with chronic TBI by combining HD-tDCS with MusicGlove exercises. Fourteen individuals with chronic TBI and hand weakness underwent 10 sessions of MusicGlove training for 45 minutes combined with either active or sham HD-tDCS. Functional outcome measures were collected before and after intervention using the Box and Block Test (BBT), MusicGlove Speed Test, and MusicGlove Dexterity Test. The between-group differences in the change score (baseline to post) of the Dexterity test were statistically significantly higher in the active group [$T=2.74$, $p=0.022$]. However, there were no observed statistically significant between-group differences in the change scores of Speed test, nor BBT, respectively. Overall, the results suggest that the HD-tDCS and MusicGlove training can potentially improve hand dexterity in people with acquired brain injury.

Investigating the Role of Mutant CHCHD10 in ALS Pathogenesis Through Mouse Models

Paridhi Tyagi

Millburn High School, Millburn, NJ

Mentor: Dr. Hibiki Kawatama, The Brain and Mind Institute at Weill Cornell Medicine

Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease that impacts motor neurons, leading to paralysis and death. Recent studies have identified mutations in the CHCHD10 gene as a contributor to ALS and other neurodegenerative diseases such as Parkinson's Disease. This research bridges the gap between genotype and phenotype by investigating how the R15L mutation impacts cellular function, specifically mitochondrial function to understand how and why it leads to ALS.



In this project, two groups were studied using mouse models: heterozygous R15L mutant mice and wild-type controls. Skeletal muscle and brain tissues were collected, homogenized, and processed to extract mitochondria for functional analysis. The mitochondrial respiration rates of the tissues were assessed using a respirometer, under various metabolic states, to evaluate differences in mitochondrial function between wild-type and R15L mutant samples. Results indicate that the R15L mutation is associated with a shorter lifespan, reduced mitochondrial respiration, and increased oxidative stress based on the mouse models. This research contributes to a better understanding of how the R15L mutation affects mitochondrial dysfunction in ALS, offering insights into the disease's molecular mechanisms. Future directions include exploring potential gene therapy-based therapeutic strategies aimed at slowing or halting ALS progression to improve the quality of life for patients with ALS.

New Jersey Southern

An Effective and Cost-Efficient Approach to Removing Phosphate Ions From Water With the Use of *Crassostrea virginica* Shells

Zachary Ciappa

Marine Academy of Technology and Environmental Science (MATES), Manahawkin, NJ

Advisor: Dr. John Wnek, MATES

After the use of fertilizers on gardens and lawns near bodies of water, it is common for chemicals (phosphates) to make their way into local waterways. It is also common for these chemicals to cause harm to the local ecosystem, mainly through the process of eutrophication. The objective of this project was to explore the possible use of *Crassostrea virginica* shells as a way to decrease phosphate ion concentration in aqueous solutions. Oyster shells were collected, disinfected, dried, and crushed into a powder. For 15 trials, 1 gram of oyster shell powder was added to 500 mL of a sodium phosphate solution. For another 15 trials, 0.5 grams of oyster shell powder was added to a sodium phosphate solution. These solutions were placed on a stir plate, where they stirred for 30 minutes at a medium speed. The collected data indicated that oyster shell powder was effective at lowering phosphate concentrations. The trials completed with 1 gram of oyster shell powder worked the best at lowering these concentrations, with a mean concentration reduction of 97.42%. The set of trials using 0.5 grams, on the other hand, had a mean reduction percentage of 54.55%. The reasoning behind the decrease in phosphate concentrations is due to the property of adsorption, which allowed for phosphate ions to cling to the oyster shell powder. This powder has relevant applications in stormwater runoff management, and can be added to stormwater basins or artificial wetlands.

Creating Durable, Low Carbon Emission Concrete Through the Use of Recycled Materials

Maggie Kelleher

Marine Academy of Technology and Environmental Science (MATES), Stafford Township, NJ

Advisor: John Wnek, MATES

The global issue of plastic mismanagement causes constant pollution, water contamination, and environmental leakage; moreover, carbon emissions (such as from cement production—a key part of worldwide concrete manufacturing processes) continuously worsen Climate Change and Global Warming. Thus, this study hypothesized that currently wasted polyethylene terephthalate plastic (PET) could instead be converted into aggregates for use in concrete—thereby reducing global plastic waste. Furthermore, if these aggregates were combined with Fly Ash, a composite used to lower concrete's cement content, it would create strong, low-emission concrete. To test this, twenty-one (four by eight inch (10.16 x 20.32 cm)) concrete cylinders were made with varying



cement-to-Fly Ash and PET-to-gravel ratios. The PET was shredded and microwave-treated for increased constituent bondage, and concrete samples were cured for 135 days before their compressive strengths were measured. A total of 4,560 ordered pairs (strain, stress) were calculated from the data. The strongest mix (15% PET, 30% Fly Ash) withstood $\approx 11,720$ lbs, while traditional concrete only withstood $\approx 5,355$ lbs, supporting the hypothesis. Additionally, it reduced CO₂ emissions (≈ 215.78 g vs. ≈ 305.51 g) and cost (\$0.85 vs. \$0.94) while recycling ≈ 0.96 cups of harmful plastic per cylinder. Based on current metrics, the 15% PET, 30% Fly Ash samples would cause: $\approx 760,000$ t reduced emissions and $\approx 4,100,000,000$ t reduced plastic waste over one year, and \$12,870,000,000 in expenses reduction over the next five years, making this an effective and essential environmental solution.

Effects of Epigallocatechin Gallate (EGCG) and Piperine Compounds on the Regeneration of *D. Tigrina*

Vinil Polepalli

High Technology High School, Lincroft, NJ

Mentors: Mr. Craig Queenan, Dr. Dina Ellsworth

Cancer treatments have been a major focus of the medical field for decades. Today, there is a need for a highly effective and affordable treatment. Epigallocatechin Gallate, a catechin in Green Tea, and Piperine, an alkaloid in black pepper, have emerged as a potential cancer treatment in recent years due to their cancer-preventive properties. *Dugesia tigrina*'s, more commonly known as planaria, regenerative properties with its neoblasts have served as a model of cancer growth when finding potential treatment. It was hypothesized that knowing EGCG and piperine both have positive cancer-preventive properties, combined treatment could prevent the cell proliferation of the planarian stem cells. To investigate this issue, The planaria were exposed to varying concentrations of Epigallocatechin Gallate and Piperine over seven days, and the percent change of growth in the regenerating planaria was recorded. Control planaria without any Epigallocatechin Gallate and Piperine concentration were placed into the Petri dishes. After the first trial, the predicted outcome was supported. After the first trial, the ideal concentrations to prevent planarian growth were obtained. The second trial was conducted using the combined treatment of EGCG and piperine. The data supported the hypothesis. All experimental groups were found to have a statistically significant difference in the percent growth of the planaria. The Epigallocatechin Gallate and Piperine could limit the planaria's growth. This supports the idea of the two compounds being used together as a cancer therapy or for other proliferative disease treatments, such as keloids and psoriatic arthritis.

Nutrient Uptake Ability of Zooxanthellae After Temperature Acclimation

Zoey Smith

Marine Academy of Technology and Environmental Science, Manahawkin, NJ

Mentor: John Wnek

Zooxanthellae, genus *Symbiodinium*, is the symbiotic microalgae that occupies coral tissue. Coral bleaching is the process in which the zooxanthellae is expelled from the host because of rising temperatures and ocean acidification, resulting in starvation and death. This study was designed to test the algae's ability to cycle nutrients after being acclimated to unusually high temperatures. Two 5L cultures of zooxanthellae at 27°C acted as the control, and three 1L variable cultures were maintained in a water bath at 30, 33, and 36°C, for four weeks each. Before proceeding to the next temperature phase, a 1L aliquot of the control culture was shocked in the water bath for one week. All six cultures were then put through a one-hour test in which nitrate levels were artificially elevated, to determine the cultures' ability to cycle nitrate. It was determined that the acclimated cultures were able to cycle the nitrate at rates comparable to the controls ($p > 0.05$), whereas the



shocked cultures' ability to do so was depleted with each increase in temperature. Furthermore, the growth rate of the acclimated cultures was nearly double that of the control ($p < 0.05$). This study demonstrates the ability of temperature acclimated zooxanthellae to thrive under stress and cycle nutrients as effectively as the control culture, offering a feasible solution to the coral bleaching crisis.

Determining the Presence of Ferulic Acid in *S. Alterniflora* and its Biogeochemical Influences within Salt Marshes at Barnegat Bay, NJ

Morgan Zylinski

Marine Academy of Technology and Environmental Sciences (MATES), Manahawkin, NJ

Sponsor: John Wnek, MATES

Ferulic acid is one of the most abundant salt marsh phenolic compounds found within the leaves of *Spartina alterniflora*. Ferulic acid is crucial in ensuring cell wall rigidity, defense against microbial invasions, and UV protection. Tidal wetlands in Barnegat Bay, NJ, have experienced intense development that led to extensive salt marsh fragmentation and loss. Nutrient loading due to stormwater runoff contributes to significant changes within the abiotic and biotic functions of the watershed. Ferulic acid can induce the resilience of salt marsh plants; however, phenolics may interfere with the soil processes and advance the accumulation of harmful nutrients within the salt marshes. In this study, three salt marshes located in Barnegat Bay were tested for sand fractions, percent organic matter, percent moisture, and soil nitrogen and phosphorus contents. Plant leaf samples from *S. alterniflora* were extracted and tested for ferulic acid concentrations using spectrophotometry methods. In analysis, increased concentrations of ferulic acid stimulated the accumulation of nitrogen and phosphorus within the soil and reduced organic matter percentages. There was also an exhibited decrease in the presence of *Melampus bidentatus* with increasing concentrations of ferulic acid. The natural presence and accumulation of ferulic acid in salt marshes have a significant influence on the cycles of other chemical, physical, and biotic properties within the tidal ecosystem. Understanding the interferences of phenolic compounds can continue to assist in the study and remediation of the increasing pollution within our tidal ecosystems.

New York-Long Island

Biophysical investigations into the structure and function of *Pseudomonas aeruginosa* nitric oxide signaling system

Natalie Osorio

H. Frank Carey High School, Franklin Square, NY

Mentor: Jason Withorn, Stony Brook University

Nitric oxide sensing proteins (NosPs), have been studied as important signaling molecules in various organisms. Particularly in *Pseudomonas aeruginosa*, NosP plays a role in heme binding and controlling the phosphorylation of NosP's associated histidine kinase, NahK. Recently, heme binding has been of particular interest and how this is associated with the signaling pathways in bacterial biofilm formation. Computational structural characterization of *P. aeruginosa* NosP predicts that heme binding occurs between the "tri-symmetrical base" and "disordered cap" regions. The cap is believed to open and secure the heme in position. Despite these predictions, the role of NosP's cap remains poorly uncharacterized. As a result, it was hypothesized that generating a NosP construct without the cap ($\Delta 208-301$) will greatly diminish kinase inhibition and heme binding during *in vivo* and *in vitro* testing. To test this, capless, tagless, NosP was generated and purified, and the apo, ferric, and ferrous complex ligation states were assessed with UV-Vis



spectroscopy. The inhibitory potential of these complexes with NahK was tested using HPLC analysis. The phenotypes downstream of NahK, such as the production of pyocyanin and swarming motility, were checked to see if the cap affects the ability of it to inhibit NahK. Interestingly, the *in vivo* data shows strong phenotypic evidence of the capless NosP exhibiting tighter inhibition, while the preliminary investigation into the capless mutant's heme binding properties show altered mechanics and reduced inhibition *in vitro*. Therefore, future work is needed to further understand how the heme binding plays a role in kinase inhibition.

Physics-Informed Machine Learning for Many-Objective Generative Design

Sean Skinner

Ward Melville High School, East Setauket, NY

Teacher: Dr. Marnie Kula, Ward Melville High School

Generative design (GD) is a computational method for the exploration of optimized engineering structures based on machine learning. Although well suited for exploring designs with various objectives, GD is often only used to generate parts which are stiff yet lightweight, ignoring the unique goals of design problems. The use of physics equations and intuition in the design of machine learning models, or physics-informed machine learning (PIML), has been demonstrated to improve machine learning models. Exploiting GD's potential for many objective design exploration, the present study proposes PIML as a method of creating a many-objective GD (MOGD) program. This proposition is demonstrated through a case study in an automotive wheel design problem, generating strong, thermally dissipative, lightweight, and diverse designs. A physics-informed neural network is developed to generate wheels based on input parameters, which are selected based on physics principles to be impactful to the performance of designs. Then, a many-objective reinforcement learning model is trained to generate sets of input parameters for the generator with sensitivity to an engineer's input regarding the priority to be placed on each objective. Connecting these models yields an MOGD program which can generate a slate of diverse designs based on the selected performance priorities. The optimal performance of the generated designs and the sensitivity of design performance to selected priorities are numerically confirmed. The present study demonstrates both PIML-based and many-objective GD, which could allow engineers to improve designs along multiple performance goals in a streamlined manner.

Evaluating Decoupling Between Radiofrequency Elements of the Coil Array in Magnetic Resonance Imaging

Emma Su

Herricks High School, New Hyde Park, NY

Mentor: Dr. Yunsuo Duan, Columbia University

Magnetic Resonance Imaging (MRI) is a vital diagnostic tool, with image quality heavily influenced by the performance of radiofrequency (RF) coils; particularly their signal-to-noise ratio (SNR), which are crucial for high-quality MRI scans. Coil over-overlap has shown to reduce coupling, or magnetic field interference, and increase decoupling between coils. Thus, I hypothesized that the use of a single coil decoupling loop would reduce coupling sufficiently in a 2-channel RF coil array. Current decoupling strategies such as critical coil overlap, help minimize coupling, but optimal conditions for 2-channel RF receive coils remain understudied. Therefore, I aimed to assess the impact of decoupling techniques on MRI image quality and resolution in a 2-channel RF receive coil array. Two different sized loops were evaluated across different coil overlap and separation conditions. The SNR was assessed after image acquisition of a spherical phantom, using a 3T MRI scanner. Furthermore, SNR was quantified, with a well-decoupled array serving as the reference standard. Findings suggest that a large decoupling loop sufficiently decouples over-



overlapped RF coils, as it achieved a high maximum SNR (492.7), which was 96.9% of the SNR of the well-decoupled SNR maximum. Furthermore, the maximum SNR of the small decoupling loop was 445.2 when the coils were not overlapped. Overall, these findings suggest that both large and small decoupling loops can minimize coupling, and may improve image quality in MRI. Future research should explore decoupling strategies for increased RF coil channels and investigate their applicability in clinical settings with human subjects.

AUM-302, a Novel Triple PIM/PI3K/mTOR Inhibitor, Offers Promising Potential in Reducing the Growth of Pancreatic Ductal Adenocarcinoma Spheroids and Organoids

Emma Wen

John L. Miller Great Neck North High School, Great Neck, NY

Mentor: Agnieszka Bialkowska, PhD - Associate Professor, Department of Medicine, Renaissance School of Medicine at Stony Brook University

Pancreatic ductal adenocarcinoma (PDAC) is an aggressive malignancy with a 13% 5-year relative survival rate. The limited number of well-defined, druggable targets in PDAC has hindered the development of effective treatments. The PIM/PI3K/mTOR pathways, which regulate cell growth, apoptosis, and metabolism, are often dysregulated in PDAC, leading to various transformed phenotypes. AUM-302, a novel triple PIM/PI3K/mTOR inhibitor, stands out for its unique mechanisms of action. It inhibits PDAC growth by directly binding to the ATP binding site of the PIM kinases and indirectly impacting the PI3K/mTOR pathways. It was hypothesized that AUM-302 has potent inhibitory effects in 3D culture. This study evaluated the efficacy of AUM-302 in human PDAC cell lines and organoids grown in 2D culture under 3D ultra-low attachment (ULA) conditions and in 3D Matrigel format. Control compounds TP-3654, GDC-0941, and BEZ-235 that primarily inhibit one/two of the 3 cell signaling pathways, respectively, and DMSO, were used. The half-maximal inhibitory concentrations (IC₅₀) of the test compounds were evaluated using a 3D CellTiter-Glo luciferase assay. The cells were imaged 24, 48, and 72 hours after treatment. In PDAC cell lines and organoids, AUM-302 induced more cell death and inhibited cell proliferation in a dose-dependent manner compared to the control compounds, as evidenced by the change in morphology of the cells and low IC₅₀ values. Overall, AUM-302 shows substantial inhibitory activity towards PDAC cell lines and organoids. Additional studies in conditions that recapitulate the human tumor microenvironment are needed to confirm AUM-302's effects.

Quantum Hilbert Transform in Logarithmic Time

Henry Zhang

Jericho High School, Jericho, NY

Mentor: Joseph Li, University of Maryland, College Park

Teacher: Alexis Vandergoot, Jericho High School

The Hilbert transform is a critical tool in signal processing, used to extract instantaneous amplitude, frequency, and phase from signals. Its wide-ranging applications include ECG signal analysis to detect heart arrhythmias, power grid control to prevent blackouts during natural disasters, and early warning systems for earthquakes and tsunamis. However, classical Hilbert transform algorithms are bottlenecked by the $O(n \log n)$ time complexity of the fast Fourier transform, especially as datasets grow to contain quadrillions to quintillions of data points. This project presents a quantum algorithm for the Hilbert transform that uses quantum parallelism to calculate the Hilbert transform in just $O(\log n)$ depth. Although general state multiplication is impossible on quantum computers, this project creates a novel quantum DC filtering algorithm which uses postselective measurement to bypass the unitary constraints of quantum mechanics. Additionally, single-qubit rotation gates are used to compute phase shifts needed for the Hilbert transform in constant time. Numerical results from IBM Qiskit on power systems and ECG data



verify that the algorithm's quantum results match exactly with classical results while requiring exponentially fewer operations, for scalable and efficient information processing on quantum computers.

New York-Metro

Synergistic Interactions Between Essential Genes and Antibiotics in *Staphylococcus Aureus*

Julia Hettleman

Packer Collegiate Institute, Brooklyn, NY

Mentor: Wan Li, Mount Sinai

Antibiotic resistance is an increasingly prevalent issue as bacteria adapt to the overprescription of antibiotics, making the treatment of bacterial infections more difficult. To combat this, the novel gene-editing technology, CRISPR, can be used to assess interactions between certain genes and traditional antibiotics in a bacterial genome. CRISPR Adaptation-mediated Library Manufacturing (CALM) is a method of manufacturing a library of crRNAs - a key molecule in CRISPR's targeting mechanism - allowing for gene repression via CRISPR inhibition (CRISPRi) of up to 90% of genes. In this project, CALM-CRISPRi libraries were constructed and treated with antibiotics. The libraries were then sequenced to identify which gene perturbations reduced bacterial fitness in the presence of antibiotics. To validate the screening, cells containing a replicated crRNA targeting a gene of interest were grown in competition with common competitor cells lacking crRNAs. The cells were grown in the presence of various antibiotics to identify any synergy between the antibiotics and the gene repression. DNA was extracted from these populations and analyzed, resulting in a final calculation of the cells' fitness. We identified synergy between similar processes; for example, the repression of a cell wall synthesis gene synergized with an antibiotic targeting the cell wall. Additionally, simultaneous repression of cell wall/cell membrane and DNA synthesis/replication genes revealed widespread synergy between the two processes. Using this data, drugs can be developed to repress the identified genes and used with antibiotics to treat bacterial infection more effectively.

Machine Learning for Identification of Fast Progressors of Infarct Growth in Early Window Acute Ischemic Strokes Without Perfusion Imaging

Sidney Lin

The Bronx High School of Science, New York, NY

Mentor: Dr. Kory Byrns, New York Presbyterian Queens

Purpose: Fast progressors (FP) of anterior circulation acute ischemic strokes at 0-6 hours from onset (early window) are associated with less favorable outcome. FP is determined by using computed tomographic perfusion (CTP) to measure infarct core volume (ICV), but CTP requires additional time, costs, and radiation, in addition to pitfalls such as patient motion. My aim was to determine if machine learning (ML) can accurately identify FP using only baseline demographic, clinical, laboratory, CT, and CT angiography (CTA) data, to bypass CTP.

Methods: Retrospective study of stroke patients arriving 0-6 hours from symptom onset with anterior circulation occlusion on CTA who had concurrent CTP. Infarct growth rate (IGR) was calculated as ICV/time from onset and FP was defined as IGR ≥ 10 mL/hour. Four ML algorithms for binary classification were trained on 11 selected features. Data were randomly split 70:30 for training and testing. 10-fold cross validation scores were assessed during training with tuning of



hyperparameters. Models were tested using areas under the receiver-operating characteristics curves (AUROC) and predictive values.

Results: 147 patients were included with median (IQR) age of 76 years (67-85), ICV of 11 mL (0-34), and IGR of 3.4 mL/hour (0-12.3). 47 (32.0%) were FP. XGBoost was the best performing ML model with AUROC of 0.900, PPV of 76.5%, NPV of 96.4%, sensitivity of 92.9%, specificity of 87.1%, and accuracy of 88.9%.

Conclusion: ML can accurately identify FP in the early window without CTP.

Mechanistic Insights into Org 43553-Induced Energy Expenditure *In Vitro*

Soleil Ava Wizman

Hunter College High School, NYC, NY

Mentor: Dr. Ofer Moldavski

The obesity epidemic, a leading driver of chronic diseases such as cardiovascular disease and type II diabetes, remains inadequately addressed by current pharmacological treatments. GLP-1 agonists, while effective in appetite suppression, frequently cause adverse side effects, including significant lean mass loss, underscoring the need for innovative therapies. Org 43553, a low-molecular-weight agonist of the luteinizing hormone receptor (LHCGR), presents a promising alternative by selectively preventing fat gain *in vivo*. This study investigates the mechanisms by which Org 43553 enhances energy expenditure *in vitro*, utilizing 3T3-L1 adipocytes as a model system. Our results reveal that Org 43553 significantly increases intracellular oxygen consumption rate (OCR) in a dose-dependent manner, independently of UCP1 activation, suggesting a unique pharmacologic pathway for fat loss induction. Furthermore, Org 43553 triggers phospholipase C (PLC) activity but not cAMP production, activating a calcium- and extracellular signal-regulated kinase (ERK 1/2)-dependent signaling cascade. RNA sequencing identified ATF3 as a key upregulated transcription factor, along with its downstream targets, suggesting its potential involvement in enhancing mitochondrial activity and energy expenditure. The role of ATF3 was further validated with siAtf3 knockdown experiments, confirming its function as a primary driver of Org 43553-induced changes in mitochondrial respiration. Ultimately, our findings uncover a previously uncharacterized non-canonical mechanism by which Org 43553 stimulates energy expenditure in adipose tissue, underscoring its potential as a next-generation obesity therapy and establishing a foundation for future research into targeted metabolic disease treatments.

Polymer-grafted SWCNTs as Synthetic Receptors

Vanessa Wu

Bronx High School of Science, Bronx, NY

Mentor: Stanislav Piletsky, PhD, Memorial Sloan Kettering Cancer Center

Single-walled carbon nanotubes (SWCNTs) are cylindrical carbon tubes capable of emitting fluorescence in the near-infrared region (NIR), which overlaps with the transparent window for imaging biological tissue. SWCNT fluorescence is environmentally sensitive, with peak wavelengths and intensity changing upon interaction with different molecules such as proteins, peptides, or lipids. To utilize SWCNTs as synthetic receptors, they must be water soluble and fluorescent; however, their hydrophobic properties quench fluorescence in aqueous solutions. A promising alternative is grafting polymers onto SWCNTs by optimizing the monomer concentrations. In this study, we successfully grafted Bis[2-(methacryloyloxy)ethyl] phosphate (PC), a polymer with a similar molecular structure to DNA, onto SWCNTs, achieving dispersion in aqueous solutions without quenching fluorescence. We found that polymer-grafted SWCNTs



exhibit stability under extreme pH conditions, making them potentially useful for imaging and examining biological tissue. We also began to develop a method to graft molecularly imprinted polymers (MIPs) onto SWCNTs to create highly specific and sensitive receptors. MIPs are synthetic antibodies with predetermined selectivity and specificity for a template molecule. A deeper understanding of polymer-grafted and MIP-SWCNTs is critical for their use as synthetic receptors, enabling imprinting with disease biomarkers. This advancement would enable early detection of diseases and significantly improve patient survival rates and clinical treatments.

New York-Upstate

Neural Biomarker-Based Diagnosis of Alzheimer's Disease: AI Models Sensitivity and Accuracy Results on Multiple Electroencephalography Data Sets

Shrey Kumar

Horace Greeley High School, Chappaqua, NY

Millions of people in the United States suffer from Alzheimer's Disease (AD), an incurable form of dementia that continues to increase in prevalence. Current methods of AD diagnosis are limited to a late stage by which time the treatment options are limited, quality of life is poor, and cost of treatment is exponentially high. Early medical diagnosis of AD is difficult since non-invasive techniques require extensive tests and still generate false positives and negatives, leading to misdiagnosis. This study proposes supervised machine learning models trained on readily available Electroencephalography (EEG) patient data to diagnose potential AD patients. Relevant features were extracted and analyzed from two open-source EEG databases, collected from 180 patients and used in four experiments to train and test the machine learning model of best fit. Our artificial intelligence (AI) model is an alternative to current late-stage detection methods which require complex and risky procedures that can lead to inaccuracies. In addition, current algorithms require feature manipulation and sort through thousands of raw EEG data points to obtain unreliable results. The results demonstrate that, given EEG data of 180 close-eyed patients, the trained logistic regression model- the machine learning model of best fit – achieved 100% sensitivity and 94% overall accuracy for the C4 electrode, using data recordings of only eight second segments for each patient. This novel AD screening tool, with a cloud-based AI model, can be easily deployed at primary health care clinics to screen patients for AD during their yearly clinical visits to increase early diagnosis.

Engineering the First Self-Taught *Tales of Tribute* Agent via Deep RL and Abstract Action Selection

Sebastian Lashmet

Byram Hills High School, Armonk, NY

Mentor: Dr.-ing Alexander Dockhorn, University Leibniz Hannover

As artificial intelligence takes over more of day-to-day decision making, it is imperative that automated systems are capable of making intelligent, well-reasoned decisions. For decades, this quality of AI has been measured through computers' mastery of increasingly sophisticated strategy games. Today, a major complexity benchmark is *Tales of Tribute (ToT)*, an enormously complicated online card game. To cope with the game's intensity, most strong *ToT* agents rely on the use of pre-existing human knowledge via the insertion of heuristic rules, dramatically reducing those agents' applicability to other domains. In contrast, this paper introduces RL-GG ("*Reinforcement Learning, Good Game*,"), the world's first self-taught agent for *ToT*. Through reinforcement learning, RL-GG teaches itself the game from the ground up, without the need for human knowledge, allowing it to be built with multi-domain versatility in mind. To do this, it utilizes



a novel action representation technique, reminiscent of LLM token architecture, that allows it to evaluate an arbitrarily large number of actions without increasing computation time. In bot-versus-bot matches, RL-GG achieves winrates ranging from $41.5 \pm 3.1\%$ to $84.4 \pm 2.3\%$, demonstrating the efficacy of its variety of improvements over vanilla RL and search-based techniques. Most importantly, these advancements produce a broadly applicable RL algorithm capable of learning delayed gratification (among other skills) from zero human input in a harshly complicated domain with extremely limited computing power. As a result, RL-GG simultaneously summits a notable challenge in computer science while also developing AI's "toolbox" of abstract reasoning methods for use on real-world problems.

Evaluation of the Performance of Breakwater Designs at a Coastal Marsh Shoreline Using a Smartphone-Based Wave Intensity Sensor (WILSON)

Nora Morton

Horace Greeley High School, Chappaqua, NY

Mentor: Jim Dugan, Mordecai Land Trust

Coastal wetlands, vital for wildlife habitat and natural flood defense, are critically threatened by sea level rise and eroding damage from wakes and waves created by recreational boating. Scientists, engineers, and coastal communities have partnered to test various "living shoreline" structures intended to reduce wave impacts on marsh. Comparing the efficacy of various breakwaters in reducing wave heights, I created a novel cost-effective wave action device, the **Wave Intensity Logging Sensor Of Nora** or "WILSON" and deployed it to compare three breakwaters protecting adjacent areas of the Intracoastal Waterway in New Jersey: Breakwater 1 (interlocking concrete blocks), Breakwater 2 (triangular concrete structures), and Breakwater 3 (geosynthetic tubes). The WILSON included an anchor, a float, and an iPhone operating SensorLog acceleration data collection. In 2024, I collected data from four units simultaneously, monitored boat and wave activity by a camera, and compared open water to individual breakwaters. Mean isolated-wave heights were reduced 57% by Breakwater 1, 21% by Breakwater 2, and only 11% by Breakwater 3, ($p < .001$) Breakwaters $\frac{2}{3}$ insignificant from open water. In 1 hour intervals of ambient waves, Breakwater 1 reduced wave height 84%, Breakwater 2 reduced wave height 70%, Breakwater 3 attenuated 51% (not significant) and waves were reduced 21% across Open Water (no breakwater) ($p \approx 0.001$). This constructed a reproducible method to collect wave data in a cost-effective manner accessible to students, teachers, or researchers. These studies can help inform coastal resilience infrastructure decisions and contribute to protection of both natural habitats and adjacent coastal communities.

Elucidating Memory Distortions in the Consolidation Process

Riya Raina

Briarcliff High School, Briarcliff Manor, NY

Mentor: Dr. Alexa Tomparry, Drexel University

Memories are not exact replicas of past events; they are influenced by prior knowledge and experiences, causing distortions that affect all humans. Although the reconstructive nature of memory is well studied, it remains unclear whether distortions arise during the encoding or retrieval stages of memory consolidation, the two phases where memories are actively processed. To address this, two experiments were conducted to identify when distortions occur and explore strategies to mitigate them. In Experiment 1, human participants memorized image locations on a novel 2D grid task. During encoding, two groups of images were learned: a pre-cluster group learned without a distorting agent, and a post-cluster group learned with knowledge of categorical clustering. Paired t-tests revealed a significant magnitude of distortions in both groups ($p < 0.01$) but no difference between pre- and post-clustering distortions. This suggests that encoding is not



a critical period for memory distortions; they likely arise during retrieval. In Experiment 2, Transcranial Magnetic Stimulation (TMS), a non-invasive brain stimulation technique, was applied to the Anterior Temporal Lobe (ATL), a brain region involved in integrating categorical schema. Participants performed the memory task from Experiment 1 in two groups with TMS before encoding and before retrieval. Paired t-tests showed that only TMS applied pre-retrieval significantly reduced distortions ($p < 0.05$). This finding provides concrete evidence that distortions occur during retrieval, supporting Experiment 1, and shows that the neuromodulation of the ATL can mitigate them. This research offers novel insights into memory and practical pathways for addressing memory distortions in real-world situations.

Characterizing the RyR2-Mediated Cardiac Pathophysiology of COVID-19 in Rodent Models

Aaron Weinberg

The Masters School, Dobbs Ferry, NY

Mentor: Steve Reiken, Columbia University Medical Center

As of 2024, COVID-19 has resulted in over one million deaths in the U.S. and seven million globally. While research has primarily focused on pulmonary manifestations, cardiovascular complications, and their pathogenesis remain a significant yet underexplored consequence of SARS-CoV-2 infection. This study characterized the pathogenesis of COVID-19-induced cardiac dysfunction, specifically the role of the ryanodine receptor (RyR2), an intracellular calcium release channel on the sarcoplasmic reticulum in cardiomyocytes. Additionally, this study evaluated s107 as a potential therapeutic agent to reduce SARS-CoV-2-induced cardiac dysfunction. Protein lysates and immunoprecipitates were isolated from the cardiac tissue of control and SARS-CoV-2-infected mice and Syrian golden hamsters. Quantitative proteomics revealed discernable protein dysregulation in SARS-CoV-2-infected samples, particularly proteins that play a role in RyR2 dysfunction. Western blotting displayed increased markers of post-translational modifications to RyR2, indicative of structural changes to the channel and RyR2 Ca^{2+} leak. This Ca^{2+} leak was then confirmed through a calcium spark analysis. Lastly, increased interstitial fibrosis (1.5-fold in mice and 2-fold in hamsters) and decreased ejection fraction (.73-fold) were observed in SARS-CoV-2 infected rodents. Treatment with the RyR2 stabilizer, s107, significantly improved calcium homeostasis by stabilizing RyR2 and improved cardiac function by restoring ejection fraction. These findings confirm the role of RyR2 in cardiac pathophysiology associated with COVID-19 and highlight s107's therapeutic potential in reducing SARS-CoV-2-induced RyR2 calcium leak and improving cardiac function. This study sets the stage for future in-vitro investigations and clinical trials, employing s107 to reduce COVID-19 morbidity and mortality.

North Carolina

AllerGel: Inhalable Bioadhesive Microspheres to Prevent Particulate Matter-Induced CRDs and CRS

Jamie Cheng

Green Level High School, Cary, NC

Mentor: Dr. Jiaming Liu, NC State University

About 30% of adults and 40% of children in the U.S. are allergic to pollen, a form of particulate matter (PM). PM exposure leads to chronic rhinosinusitis (CRS) and chronic respiratory diseases (CRDs), a leading cause of death. As someone with CRS, I can attest that current prevention methods, including masks and over-the-counter products, are inconvenient and ineffective. This study introduces AllerGel, an inhalable powder that transforms into a hydrogel upon contact with



mucosal fluid, and I hypothesized that it will prevent PM from reaching and reacting with epithelial cells through effective capture, adherence, and allergen neutralization. I tested PM adsorption and adherence on the hydrogel using SEM and CLSM, penetration of allergenic proteins through the hydrogel by conducting western blot, and swelling behavior of AllerGel microspheres in various solutions. The results revealed that AllerGel microspheres swelled and successfully formed a hydrogel in mucus-like solutions. Regarding the physical barrier, the hydrogel had higher PM adherence and adsorbed more PM than the control, confirming AllerGel's bioadhesive properties. Regarding the chemical barrier, AllerGel had minimal allergenic protein penetration through the hydrogel, unlike Nasaleze®, a similar commercial product, which had more allergenic proteins penetrating due to the lack of a chemical barrier. AllerGel can be administered via a nasal spray bottle and both the hydrogel and PM are naturally removed from the body within 24h of application through biodistribution and mucociliary clearance. AllerGel offers targeted and localized prevention of PM-induced CRDs and CRS, potentially benefiting millions of people worldwide.

Mitigating Toxicological Effects of PS-NH₂ Nanoparticles on *Chlorella* sp. in Heavy Metal Remediation Systems using Humic Acid

Luca Cyrus

Weddington High School, Matthews, NC

Mentor: Dr. Oyla Keen, UNC Charlotte

Nanoplastics are artificial polymers ranging from 1 µm to 1 nm. There has been a huge increase in nanoplastics due to the environmental degradation of microplastics via wind, water, and UV degradation. Nanoplastics have not been as studied as microplastics due to their minuscule size, making them harder to detect. More research has come out recently showing the true abundance of nanoplastics in terrestrial and aquatic ecosystems. Nanoplastics have been found in great quantities in tap and bottled water leading to the ingestion of nanoplastics in both animals and humans. Microalgae-based Water Treatment Technologies (MWTT) have been rapidly researched recently as they serve as a more eco-friendly alternative method compared to conventional storm and wastewater purification techniques of organic compounds and heavy metals. Many papers have shown there may be a correlation between increased nanoplastic concentration and toxicological microalgae. If a positively charged nanoplastic such as PS-NH₂, it will increase the chemical distress it causes on the microalgae, and impact various organelles such as the mitochondria, cell vacuole, and cell membrane. However, humic acid is known to change the zeta potential of the NPs and thus mitigate its effects due to the lessening of the van der Waals force. This study hopes to better understand the biochemical process of nanoplastic toxicity in the genus *Chlorella* Sp. how humic acid can mitigate positively charged nanoplastic toxicity and analyze the efficacy of heavy metal remediation of copper and zinc.

DISTRACT: Driver Inattention State Transition Recognition using Attention-based Convolutional Transformers

Ronit Dey

North Carolina School of Science and Mathematics (NCSSM), Durham, NC

Teacher: Mr. Robert Gotwals, NCSSM

Mentor: Mr. Daniel Egger, Duke University

Distracted driving represents an escalating public safety crisis, with its role in motor vehicle collisions and resulting fatalities steadily increasing. Despite advances in distracted driving classification (DDC) systems, current approaches remain limited to detecting distraction. They fail to model or quantify a driver's attention over time, a key limitation preventing adaptive and intelligent safety systems. In response, this study introduces the DISTRACT model. This



comprehensive system combines advanced computer vision with human attention dynamics to enhance distraction detection and enable real-time quantification of driver attention. The DISTRACT model integrates three key components. First, it features a hybrid Convolutional Neural Network (CNN)-Vision Transformer (ViT) image classification model that classifies nine distinct driver states with exceptional accuracy, achieving an F1-Score of 95.51%. Next, those classifications are converted into probabilities and smoothed using a Simple Moving Average (SMA) to identify transitions between normal driving and distraction. The time-series analysis exhibited just a 10.78% average error in estimating distraction length. Lastly, a severity quantification function translates the distraction duration into a 0-1 severity score. This function was derived from empirical crash risk data, reflecting the exponential increase in crash risk associated with prolonged lengths of distraction. Integrating the DISTRACT model's severity score into ADAS could allow vehicle safety systems to proactively adapt to driver attention levels rather than react to emergencies, marking a new paradigm in intelligent driver monitoring. By transforming the DISTRACT model from concept to reality, we can pioneer intelligent and adaptive vehicular safety systems that save countless lives.

Enhancing Cybersecurity in DER-Based Smart Grids with Blockchain and Differential Privacy

Noga Gercsak

David W. Butler High School, Matthews, NC

Mentor: Dr. Cori Faklaris, UNC Charlotte

The increasing integration of distributed energy resources (DERs) into smart grids has enhanced energy management in power systems. However, this development also makes DERs more vulnerable to cyberthreats through various technical and human vulnerabilities (e.g., the 2015 Ukraine power grid cyberattack). Enhancing the DER-based smart grid's cyber-resiliency is becoming highly critical and attracts interest from both industry and academia. Existing research has proposed various security frameworks and protective measures, but they neither focus on specific attack vectors nor can provide holistic protection across the full scope of vulnerabilities. To address these critical gaps in grid security, this paper proposes a novel framework that uses blockchain technology and differential privacy to enhance the cybersecurity of DER-based smart grids. The framework includes a lightweight blockchain for dynamic certificate management to enable secure and immutable communication between DER components. Additionally, differential privacy is integrated by adding calculated noise to data (i.e., random values that are intentionally added, anonymizing sensitive data while maintaining utility). Key metrics, such as transaction latency, certificate issuance time, and resilience to cyberattacks, are analyzed to evaluate the scalability and effectiveness of the proposed solution. My experimental results demonstrate competitive performance, with block creation times averaging 0.85 seconds and attack recovery times under 40 microseconds, comparing favorably to traditional solutions, which typically show latencies ranging from 2ms to 423ms for similar security operations in SCADA and substation networks. These findings reveal the potentials of both blockchain and differential privacy protecting smart grid ecosystems toward security with scalability.



Investigating the Influence of Coal Ash Heavy Metal Leachate on Thyroid Hormone Concentration, Hormone Receptor Gene Expression, and Spectral Sensitivity in *Danio Rerio*

Anna Theresa Marie Christopher Tringale

North Carolina School of Science and Mathematics, Durham, NC

Mentor: Heather Mallory

As global energy needs have skyrocketed in the past decade, energy byproduct has increased in tandem. Places like Mooresville, North Carolina; Pineville, Indiana; and southeastern Puerto Rico serve as coal ash fill sites and cancer cluster hotspots. Yet, as energy companies deny any link between ash and endocrine disruption, evidence points to ash heavy metals prompting thyroid toxicity. The goal of this study was to determine if coal ash heavy metal leachate can alter the light sensitivity, gene expression, or hormone production of thyroid processes within *Danio Rerio*. *Danio rerio* or zebrafish larvae were chosen to replicate disruption, as they have recently emerged as a model organism for thyroid diseases and disorders. To quantify endocrine disruption, zebrafish were exposed to artificially created coal ash leachate, and raised until 6dpf. As zebrafish color cones show insights into thyroid-catalyzed morphological development, zebrafish larvae movement was recorded in response to specialized light sequences. RT-PCR was performed to determine potential disruption in the regulation of thyroid-related genes, namely TPO, DIO2, DIO3, and THR β . Finally, immunosorbent assay kits quantified the amount of thyroid hormone TH4. Results indicate that coal-ash leachate significantly disrupts zebrafish behavioral response and gene expression, but not TH4 hormone levels. Additionally, results provide novel insights into zebrafish medium-wavelength color cone development. As legislation surrounding coal ash containment continues to weaken, the outcomes of this experiment will be invaluable to communities around the globe— seeking to uncover possible connections between ailments afflicting their neighbors and the coal ash that underlies their homes.

North Central

FULL MOON: A Novel and Economical Method for Sustainable Agriculture on the Moon

Quinn Hughes

Minnetonka High School, MN

Lunar colonization will require sustainable agriculture using *in-situ* resources and minimal fostering materials from Earth. This study aimed to grow *Raphanus sativus* (radish) in a Lunar South Pole Regolith Simulant (LSP-2) substrate that yields plant biomass statistically non-inferior to Earth-soil control plants. Previous studies using augmented 75% lunar regolith simulant (not LSP-2) grew stressed plants. Research is needed to support full-growth, nutritious agriculture while reducing fostering materials from Earth. Analysis of LSP-2's chemical and physical properties indicated that augmentation is needed to support agriculture; including acidification, nitrogen fortification, microbe introduction, humus creation, and drainage. This experiment augmented LSP-2 with drainage, soil (15 mL per sample) and a substrate top-layer that was developed over each of four ten-week growth cycles integrating Lunar-grown *Trifolium repens* plant biomass as biofertilizer for the subsequent cycle. 100% LSP-2 plants did not sprout. After growth cycle 1 (G1, no biofertilizer), average radish biomass was significantly lower than control ($p < 0.01$). After G2 (one cycle of biofertilizer worked into the top layer), average plant biomass increased (+17%), but was lower than control ($p < 0.01$). After G3 (two biofertilizer cycles), average radish biomass increased 92%, inferior to control ($p < 0.01$). After G4 (three biofertilizer cycles), the average dry biomass grew 48%, non-inferior to control ($p = .4151$). The null hypothesis is rejected. This approach, using just 4% Earth soil, a custom drainage system and three cycles of



Lunar-grown biofertilizer, is the first method to successfully grow plant biomass in augmented LSP-2 non-inferior to Earth-grown crops.

A Novel Analysis of Cosmetic Methylparaben in Artificial Amniotic Fluid

Shefali Meagher

St. Paul Academy and Summit School, St. Paul, MN

Teacher: Ms. Karissa Baker, St. Paul Academy and Summit School

This study explored the effects of varying concentrations of cosmetic methylparaben on the pH, viscosity, and glucose levels of artificial amniotic fluid. It was hypothesized that increasing methylparaben concentrations in the amniotic fluid would lower pH, increase viscosity, and elevate glucose levels. Solutions containing 0 ng/mL, 8.02 ng/mL, and 16.04 ng/mL methylparaben were prepared, with five replicates for each concentration. pH levels were measured using a calibrated Vernier pH glass-body sensor, revealing a slight yet statistically significant decrease in average pH across the concentrations. While the results supported the hypothesis that methylparaben decreases pH, there was a non-linear trend observed that warrants further investigation. Viscosity was calculated using the falling-sphere method, where a sphere of known density was dropped into the solutions to find the velocity, which was then put into the viscosity equation. Methylparaben showed no significant effect on viscosity; however, the method used may have limitations in reliability. Finally, glucose levels were assessed with test strips designed for water-based solutions, which included a color chart corresponding to glucose concentrations of 0, 36, 90, 270, and 720 mg/L. Average glucose levels remained consistent across all concentrations, indicating no measurable impact of methylparaben. Methylparaben could have an effect on glucose levels, but the minuscule concentrations found in female amniotic fluid during pregnancy may not be high enough to produce any actual impacts.

Turf Trouble: Does The DEET In Bug Repellent Really Kill Grass? Year II

Selena Qiao and Abigail Endres

Breck School, Golden Valley, MN

Teacher: Kati Kragtorp

There is anecdotal evidence that suggests bug sprays containing DEET damage grass, but there are no rigorous peer-reviewed studies on the topic. DEET, or N,N-diethyl-meta-toluamide, is a neurotoxin that affects the olfactory receptors in insects and vertebrates, inhibiting their ability to locate humans and causes transient neurotoxic effects in insects. However, there are no published studies on DEET's effect on plants. In Year I of this study, we demonstrated that bug sprays containing DEET kill grass. This year, we created our own solutions with different concentrations of DEET with 60% ethyl alcohol to identify what chemical compound within the bug spray was damaging the grass. To standardize our treatment and planting procedure, we created 3D-printed tools using Solidworks and developed quantitative methods to analyze changes in grass color. Direct spraying of solutions containing DEET killed grass in a dose-dependent manner in both a controlled, indoor environment and on three different species of grass in an outdoor environment. Grass that died due to DEET exposure did not recover even up to 30 days after exposure. The application of DEET to the soil damaged nearby grass and was almost identical to damage from direct application. Furthermore, an untargeted metabolomics analysis of treated grass revealed significant differences in metabolomes of treated grass within 1 hour of DEET application, indicating a rapid toxic mechanism. Our results are the first rigorous demonstration that it is the DEET in bug spray, not the ethanol, that kills grass.



Health Evaluation Robot for Basil - HERB

Alexandra Sigmond and Benny Marmor

Breck School, Golden Valley, MN

Teacher: Kati Kragtorp

Human crop monitoring is inefficient due to high cost and low speed, as specially trained people must individually check each plant for problems. To address this issue, research on autonomous crop monitoring has grown exponentially in recent years. Development of each monitoring system must address three, related issues: 1). the physical means of navigating the planted area to collect information, 2). the method of detection and, 3). the method of analysis that can lead to identification of deficiency. Monitoring systems for greenhouses are especially lacking. We designed and built a robotic system tailored to the application of machine learning on nutrient deficiency detection in hydroponic basil in greenhouses. The robot successfully navigated by following testing on lines on the ground and the imaging system successfully moved, detected, captured, and sent images of QR codes from a Raspberry Pi to a computer for analysis. Initial trials of images taken manually of hydroponically grown basil produced promising results for the use of Top Projected Canopy Area (TPCA) as a measure of nutrient deficiency. This flexible design is capable of collecting imaging data for other methods and analysis, like textural features, and was designed to operate seamlessly in most greenhouse environments. The analysis methods described here serve as a proof of concept for this approach, and could eventually be expanded to a variety of crops.

Decoding Diabetes: Harnessing AI to Accurately Predict Real-Time and Future Blood Glucose Levels for Diabetes Management Using Diet, Exercise, Insulin Intake, and Heart Rate Variability

Riddhi Singhvi

Stillwater Area High School

Oak Park Heights, MN

Teacher: Ms. Princessa Hansen, Intermediate School District #287

Continuous glucose monitoring (CGM) systems are crucial in diabetes care but focus solely on monitoring blood glucose levels (BGL), neglecting diet, exercise, and medication and lacking predictive capabilities. This study introduces Dual Temporal Recurrent Ensemble (DTRE), a novel AI model enabling real-time BGL monitoring without traditional CGM and forecasting BGL for 30-120 minutes when integrated with CGM data. This research hypothesized that DTRE would achieve superior prediction accuracy in forecasting over multiple time horizons compared to existing models, provide clinically acceptable real-time glucose predictions using non-invasive biomarkers, and demonstrate better accuracy with higher-frequency datasets.

The model combines advanced machine learning architectures through two parallel branches, integrating key biomarkers including diet, exercise, insulin intake, heart rate, and heart rate variability. This research is the first comprehensive study on developing and testing AI models on two diverse datasets (OH1OT1DM and D1NAMO) with different sampling frequencies. DTRE achieved forecasting accuracy with a Mean Absolute Relative Difference (MARD) of 7.6% at 30 minutes and 19.2% at 120 minutes, outperforming existing models by 13-41%. For real-time BGL predictions, DTRE surpassed commercial CGM systems with a MARD of 7.17% on the D1NAMO dataset compared to FreeStyle Libre 3 (7.9%) and Dexcom G7 (8.2%).

The results confirmed the hypotheses by exceeding clinically acceptable benchmarks in multi-horizon and real-time BGL prediction. Future research should explore integrating additional data



elements, incorporating modern wearable devices, Type 2 Diabetes, and expanding datasets to more diverse populations to create accessible and effective diabetes management tools.

Ohio

Design and Testing of an Adjustable Functional Near-Infrared Spectroscopy (fNIRS)

Nikhil Bhimireddy

Olentangy Orange High School, Lewis Center, OH

Mentor: Dr. Eric Nelson, Nationwide Children's Hospital

Functional near-infrared spectroscopy (fNIRS) is a valuable neuroimaging tool due to its safety, portability, and suitability for diverse populations. However, traditional fixed-size fNIRS caps often produce poor data quality, prolonged setup times, and participant discomfort, particularly for individuals with darker skin tones or thick hair textures. This study introduces a novel adjustable fNIRS cap featuring a 360-degree dial-lacing system, flexible neoprene-nylon fabric, and modular 3D-printed optode holders to ensure precise and consistent sensor placement. The hypothesis was that this adjustable cap would offer similar or better data quality compared to standard fixed-size caps due to its tailored fit, while also reducing setup times and enhancing user comfort. To test this hypothesis, the adjustable cap was compared with the commonly used EasyCap in a pilot study involving 15 adult participants with varying head sizes (51–58 cm), hair types, and skin tones (Fitzpatrick scale 1–5). The adjustable cap achieved a significantly higher average optimal (Green) signal quality (82.3%) compared to the EasyCap (45.4%). Improvements were especially evident among participants with darker skin tones (24.2% higher) and curly hair textures (55.8% higher). Additionally, the setup time was dramatically reduced from 25–30 minutes to seconds, and participants reported increased comfort and reduced motion artifacts. These findings support the hypothesis and highlight the adjustable cap's potential to improve inclusivity, reduce logistical burdens, lower costs, and enhance data quality in neuroimaging research and clinical practice. Future studies should further validate these benefits across broader populations.

Advancing Epileptic Seizure Prediction using a Machine Learning-Based Wearable Device

Rebecca Jacob

Solon High School, Solon, OH

Epilepsy, a brain disorder causing recurring seizures, affects approximately 65 million people worldwide, making it one of the most common neurological diseases. Additionally, epilepsy severely reduces individuals' quality of life, with a disability-adjusted life year (DALY) of 0.657—where 1 represents full disability—, indicating a substantial reduction in health. There is a need to predict seizures in real time, and warn patients or caregivers of imminent seizures. I hypothesized that machine learning, implemented in a wearable device, could achieve this. Using two datasets—CHB-MIT and Siena Scalp EEG—comprising 1160 hours of data from patients aged 0.5 to 71, four models were trained for seizure detection (K-Nearest Neighbors, Logistic Regression, Random Forest Classifier, Support Vector Machine) and one for prediction (Long Short-Term Memory). Evaluation metrics, including accuracy, recall, precision, and F1-score, showed a detection accuracy of 98.67%. Subsequently, the model was integrated with a wearable EEG headset (Muse) and a web app was developed that successfully predicts seizures 5 minutes ahead of time, with 84.54% accuracy. This work demonstrates the potential of machine learning to enhance seizure prediction and improve patient safety.



A Novel Analysis on the Effects of Changes in the Social Vulnerability Index and its Subcategories on Changes in Survival Rates for Six Common Cancers from 2000-2020

Anshul Sharma

University School, Hunting Valley, OH

Teacher: Dr. Mostafa Roustia, University School

Mentor: Dr. Fredrick Schumacher, Case Western Reserve University

The Social Vulnerability Index (SVI) measures health vulnerability based on four subcategories: socioeconomic status, household characteristics, housing type, and racial and ethnic minority status. SVI factors can cause epigenetic changes that increase cancer risk, making its correlation important to study. Previous studies established correlations between static SVI and cancer survival rates. This study explores the effect of changes in county-level SVI values from 2000 to 2020 on changes in three-year survival rates for six common cancers: breast, cervical, colorectal, lung, melanoma, and prostate. Due to past support that SVI and cancer survival rates are directly correlated, long term correlations were also hypothesized to trend in the same direction. SVI and Surveillance, Epidemiology and End Results (SEER) survival rate datasets were run through rigorous exclusion criteria and categorized based on degree of change. Multinomial logistic regressions in R were employed to examine the direction of correlations between the overall and subcategory SVI values and survival rates. This study revealed a non-uniform relationship between changes in SVI and cancer survival, with unexpected findings such as direct correlations between increased survival rates and vulnerable minority populations in breast and prostate cancers, partially disproving the original hypothesis. Findings also reveal the varying influence between different SVI factors across cancers, possibly aiding in creating tailored policy interventions that can jointly address multifaceted health vulnerabilities in the future. This study could help policymakers identify communities for long term, targeted interventions across cancer types. Further research is needed to expand these findings across additional contexts and populations.

EGCG: A Novel Therapeutic, Natural Product Inhibiting CDK5-Mediated Phosphorylation of CRMP-2 and Tau in Alzheimer's Disease

Nandita Srikumar

Solon High School, Solon, OH

Mentor: Dr. Matthias Buck, Case Western Reserve University

Alzheimer's disease is a neurodegenerative disorder characterized by the hyperphosphorylation of Tau and collapsin response mediator protein (CRMP-2), a newly identified Alzheimer's signaling pathway protein. Hyperphosphorylation of these proteins is caused by deregulated cyclin-dependent kinase-5 (CDK5) protein function. This increased phosphorylation activity leads to neurofibrillary tangles (NFTs), composed of hyperphosphorylated Tau and CRMP-2, leading to a loss in neuronal synaptic communication. Thus, all three proteins are potential targets to alleviate the impacts of Alzheimer's. There is a lack of consensus on the molecular basis of Alzheimer's, leading to inadequate treatment. Epigallocatechin-3 gallate (EGCG), a catechin found in green tea, has neuroprotective properties against inflammation of neural tissue and is an emerging medicinal herb with promising results. This paper explores the molecular interactions of proteins involved in Alzheimer's and hypothesizes that EGCG may impede such interactions. To examine EGCG's effects on key Alzheimer's proteins, binding affinities between CRMP-2, CDK5, and Tau were characterized in the presence or absence of EGCG, using microscale thermophoresis (MST). The results indicated that EGCG decreased the binding affinities between the proteins. Kinase assays were conducted to uncover the impact on CDK5's phosphorylation, revealing that the addition of CRMP-2 or Tau to CDK5 increased CDK5's phosphorylation of Tau and CRMP-2. However, the addition of EGCG to the CRMP-2-CDK5 mixture and EGCG to the



Tau-CDK5 mixture moderately decreased CDK5's activity. Computational studies were conducted to determine binding sites and corroborate the binding results. Overall, the results suggest that EGCG could inhibit CDK5-mediated phosphorylation of Tau and CRMP-2.

Positive Association between Degenerative Cervical Myelopathy and Trigeminal Neuralgia

Elainie C. Theodorou

Hathaway Brown School, Shaker Heights, OH

Mentor: Dr. Robert J. Trager, University Hospitals of Cleveland

Trigeminal neuralgia (TN) is an idiopathic pain disorder, classified by paroxysmal pain in the face. The spinal trigeminal tract extends into the spinal cord as far as the fourth cervical vertebrae, and limited research suggests that cervical spine compression may be a risk factor for TN. We hypothesized that adults with TN would have a greater likelihood of concurrent degenerative cervical myelopathy (DCM) compared to matched adults without TN. The data utilized in this study spanned the past 20 years and were obtained from TriNetX, a national database with de-identified medical records from 113 million patients across 79 million healthcare institutions. Two groups of adults (≥ 18 years of age) were created: patients with (1) TN and (2) No-TN excluding predisposing conditions for TN (e.g. multiple sclerosis, ophthalmic and oral/maxillofacial surgery), then groups were propensity matched (e.g., age, sex, body mass index, diabetes mellitus, hypertensive diseases, migraine, osteoporosis) to minimize between group differences. After matching, both groups consisted of 37,163 patients and the mean point prevalence was 0.55% in the TN group (95% CI: 0.47–0.63%) and 0.04% (95% CI: 0.03–0.06%) in the No-TN group, resulting in an odds ratio of 12.94 (95% CI: 7.78–21.53; $p < 0.0001$). The present data show that adults with DCM are over 12 times as likely to have concurrent TN. These findings support our hypothesis and suggest that DCM may be a risk factor for TN.

Oregon

Polynomial Time Algorithms for Covering Problems Using Extraction Theorems with Small Extraction Numbers

Arjun Agarwal

Jesuit High School, Portland, OR

Covering problems, a class of combinatorial optimization problems, play a crucial role in addressing various challenges in computational biology, wireless and sensor networks, VLSI design, robotics and image processing. For instance, identifying a minimal gene set that satisfies certain biological requirements such as enabling essential functions or covering key pathways can be abstracted as a covering problem as each gene “covers” a subset of these necessary processes. In a typical covering problem, given a set of points and a set of geometric objects covering these points, the goal is to pick a subset of objects whose union contains the input points (i.e., cover them) while optimizing a certain objective function. In this work, we develop Extraction Theorems for classes of geometric objects with small extraction numbers. These classes include intervals, axis-parallel segments, axis parallel rays, and octants. We investigate these classes of objects and prove small bounds on the extraction numbers. The extraction number is determined from a proper κ -coloring of the corresponding hypergraph. The tightness of these bounds is demonstrated by examples with matching lower bounds. Polynomial-time algorithms are developed to determine the proper κ -coloring, and therefore the minimum covering. These algorithms can form an essential component in addressing coverage-based strategies for large datasets, thereby efficiently providing optimal solutions.



Helios-X: A Novel Low-Cost Sensorless Solar Tracking and Forecasting System with Astrophysics-Based Positioning, Sky Image Cloud Detection, and Deep Learning

Andrew Ma

Jesuit High School, Portland, OR

The rapid growth of artificial intelligence, particularly generative AI models, has significantly increased energy consumption due to high computational power and continuous electricity demand in data centers. As global energy demands rise, the climate crisis pushes for a shift toward clean, sustainable energy. Solar energy is pivotal, yet maximizing photovoltaic (PV) efficiency remains challenging due to widely adopted fixed-angle panels and costly sensor-based tracking systems. This work introduces Helios-X, a low-cost, dual-axis solar tracking and forecasting system designed to enhance solar energy capture.

Helios-X utilizes astrophysical algorithms, calculating the sun's azimuth and elevation. To improve accuracy under cloudy conditions, a sky image processing module leverages normalized red-blue ratio (NRBR), Clear Sky Libraries (CSL), and Removal of Atmospheric Scattering (RAS) Channels to detect cloud patches and estimate real-time cloudiness. Additionally, cloudiness helps determine what algorithm is used. Running on a Raspberry Pi, the hybrid control system dynamically adjusts solar panel orientation—clear, partly cloudy, or overcast—by controlling the motor with different algorithms. The system monitors the sky and tracking angles, and stepper motors make real-time adjustments as conditions change. Additionally, sky images are used by a trained Convolutional Neural Network (CNN) model to predict short-term solar output, improving adaptive energy management and optimizing PV performance.

Being cost-effective without sensors, Helios-X keeps tracking deviations under 1.5° and boosts energy efficiency by up to 30% over fixed panels. In-field testing across seasons will validate reliability and scalability, making it a viable solution for small- and large-scale PV installations and smart grid integration.

FoGDTECT: A Novel Non-Invasive Freezing of Gait (FoG) Monitoring Solution Integrating Machine Learning and Mobile App-Generated Triaxial Accelerometer Data

Akash Ragam

Jesuit High School, Portland, OR

This revolutionary solution uses multivariate machine-learning time-series models to detect freezing of gait (FoG) instances in individuals with Parkinson's disease (PD) based on accelerometer data from a smartphone. One of the most profound symptoms of PD, FoG manifests as abrupt episodes of walking hesitation or immobility and impairs a patient's balance, increases falls, and reduces overall quality of life. This study compares the performance of various machine learning models on a FoG-accelerometer dataset and optimizes a model to accurately detect and plot instances of FoG in real individuals based on mobile-app-generated accelerometer data. Performance was evaluated using standard ML model metrics, and graphs of detected FoG instances were validated by Balance Disorder Lab Engineers at OHSU. Results highlight that the LSTM with Attention Mechanism had the best performance, with an accuracy of 0.875, precision of 0.602, recall of 0.495, and F1 score of 0.818. The uniqueness of this solution involves the ease of implementation of these models by fitting them to accelerometer data collected from a smartphone, achieving an average accuracy of 0.809. After optimizing the data collection and processing by creating an Android app, the model successfully detected and graphed FoG events corresponding to timestamps with an industry-grade average accuracy of 0.809. The efficacy of this model highlights the potential to become a non-invasive long-term



monitoring solution for individuals with PD. This can lead to proactive management, personalized treatment plans, and enhanced safety through real-time feedback, to minimize the risk of falls associated with FoG.

A Low-Cost Biocomputational Framework for Identifying Novel Malaria Inhibitors Targeting Plasmodium Falciparum

Kavin Ramadoss

Sunset High School, Portland, OR

Mentor: Dr. Kamal Singh, University of Missouri

Malaria is the third deadliest disease with around 249 million cases annually, particularly in tropical regions. Malaria is caused by Plasmodium parasites transmitted through the bite of Anopheles mosquitoes and is a global health burden. Malaria remains difficult to treat due to growing drug resistance. Malaria drug discovery is a costly and lengthy process, requiring over a decade and approximately \$3 billion before a compound reaches approval. To combat this issue, I created AutoFilter, a low-cost and novel biocomputational framework that combines machine learning (ML) and screening tools to streamline the filtering of large chemical databases for better drug discovery. AutoFilter sequentially: (i) screens compounds violating basic chemical filters such as Lipinski's Rule of 5, Vebers, and PAINS, (ii) docks each compound in the cleaned database and analyzes post-docking interactions. Following docking, AutoFilter conducts ADME filtration to identify compounds with favorable drug-like properties. Then, AutoFilter uses an ML model to predict the toxicity and synthetic accessibility of the compounds. The final step is molecular dynamics, which further refines the selected compounds for stability. I applied AutoFilter to screen the ChEMBL database, a chemical database with 2.4 million bioactive drugs, to identify malaria inhibitors targeting Plasmodium Falciparum apPOL. The five final selected compounds have high inhibition performance and favorable drug-like properties and are undergoing in vitro synthesis. AutoFilter is the first integrated biocomputational framework for screening chemical databases and is expandable for all diseases. It efficiently identifies inhibitors, reducing current costs and time by 50%, and saving many lives globally.

Development of an EpCAM-specific, Near-Infrared Fluorescent Probe for Noninvasive DiFC Detection of Circulating Cancer Cells: A Novel Approach to Liquid Biopsies for Early Cancer Diagnosis

Ashvika Singhal

Sunset High School, Portland OR

Mentor: Nicole Rueb, Oregon Health & Sciences University (OHSU)

Professors: Summer Gibbs (OHSU) and Mark Niedre (Northeastern University)

Over 50% of cancers are diagnosed at an advanced stage, greatly reducing treatment efficacy. Early cancer detection significantly improves survival rates, but current methods are invasive or limited to 6mL of blood analysis. Blood-based cancer diagnosis focuses on detecting circulating tumor cells (CTCs), which are present in low concentrations in the blood. However, recent research suggests that CTCs merge with immune cells to form circulating hybrid cells (CHCs), which are ~10 times more abundant than CTCs. Both CTCs and CHCs overexpress the protein EpCAM, whose extracellular location makes it an ideal diagnostic target. This project synthesized a near-infrared (NIR) fluorescent probe to detect EpCAM by conjugating the EpCAM-specific peptide SNFYMPL to the NIR fluorophore AF647. The probe's specificity was tested using fluorescence microscopy and flow cytometry on mouse cancer cell lines. The probe was further integrated into diffuse in vivo flow cytometry (DiFC), a tool that noninvasively counts fluorescently labeled cells in flowing liquid. In DiFC, NIR light was passed through flowing samples of A431 cells, with fluorescent signals recorded by the probe. Experiments found a 15% detection rate.



Although this seems low, this molecule's small size (40x smaller than existing EpCAM locators), and its ability to detect both CTCs and CHCs across cancer types combined with DiFC technology's potential to scan the entire blood volume holds significant promise as a step towards noninvasive comprehensive screening.

Pennsylvania

Powerful Plastics: The Effect of Glycerin on a Bioplastic Made with Sargassum Seaweed

Veda Gandhi

Parkland High School, Allentown, PA

We are currently consuming over 380 million tons of plastic each year, and 50% of that waste is from single-use plastics. These plastics only have a “working life” of 15 minutes, but they take over 300 years to decompose. The purpose of this experiment was to develop a biodegradable seaweed bioplastic that has the potential to replace single-use plastic, while putting to use the excess Sargassum seaweed washing up on our beaches due to climate change. The original research question was, “What is the effect of increasing the concentration of glycerin on a bioplastic made with Sargassum seaweed?” When alginates, which are present in seaweed, are combined with glycerin and vinegar, it creates gel-like formations. This produces a flexible and strong film, similar to customary plastic used today. For this experiment, the tensile strength, water vapor permeability, and oxygen transfer rate were tested. Testing was conducted through an at-home setup for water vapor permeability and tensile strength, whereas oxygen transfer rate testing was done in a lab, with the appropriate equipment. At the end of the experiments, the researcher concluded that as more glycerin is added, the oxygen transfer rate and water vapor permeability are increased, while the tensile strength is lowered. This finding allows this bioplastic to be customized for a myriad of applications allowing for large scale adoption which in turn, reduces the use of traditional plastics.

illumiLOGIC: Redefining Illumination through Multi-Sensor Integration

David Markwood

Muhlenberg High School, Reading, PA

Teacher: Dr. Audrey Smeltzer Schwab

Streetlights are essential to urban infrastructure and proper illumination but consume excessive energy regardless of actual usage, demonstrating the need for a more energy-efficient street lighting system through the use of external sensors and data. The hypothesis proposes that integrating passive infrared (PIR) and acoustic sensors into an adaptive lighting system will reduce energy consumption by at least 30% whilst remaining 75% accurate compared to traditional systems while maintaining effective illumination. The adaptive streetlight prototype, featuring an HC-SR501 PIR sensor, an MAX4466 microphone, Arduino Uno Rev 3, and an ESP32 microcontroller, logged root mean squared (RMS) noise, peak noise, and PIR detection, along with time and weather data. Statistical analysis confirmed significant differences between the presence and absence of each variable, and a logistic regression model was implemented to predict presence based on sensor data, with an accuracy of 84.63%. The system uses this presence prediction to determine the brightness of the LED, which utilizes a rolling average for smooth transitions, a max brightness threshold, and a weather-adjusted safe minimum brightness level. The final model achieved a 50.29% reduction in energy usage compared to a traditional streetlight, based on the controlled 67% presence rate testing scenario. This translates to \$21.15 saved per streetlight annually— or \$6.66 million annually if implemented in New York



City. These findings validate the hypothesis, demonstrating substantial energy and cost savings while maintaining high detection accuracy and safety.

PPV Communication in Pregnancy: Mental Health Questions During the First Visit in Pregnancy

Alexandra Meier

Saint Joseph High School, Natrona Heights, PA

Teacher: Mrs. Cathy Greco

This project evaluated the significance of mental health conversations during pregnancy. According to Ahrens et. al (2023), women who have prenatal depression become more likely to develop postpartum depression. This creates the need for providers to be able to diagnose and treat mental health issues both before and after the baby is born (Ghahremani et al. 2022). This study was conducted using data from the study, *Talking to Pregnant Patients* (Chang et al. 2017). The questions being raised are as follows: Were the number of questions on the first visit different by race? Did a present third party affect their openness about mental health? Does the year of a resident matter? Do advanced practice providers' questions asked differ from resident medical doctors (MD) and doctors of osteopathic medicine (DO)? These questions were analyzed using the transcripts provided from the *Talking to Pregnant Patients* study. The hypotheses were based on literature research and were that race would not affect the questions, a third party would affect the questions, the year of training in residence would affect the questions, and advanced practice providers would ask more questions than the doctors. Through a Fisher-Exact test, it was found that black patients were significantly less likely to be asked about their mental health than white patients. This accepted part of the hypothesis and rejected the other parts.

ParkinSense: A Telehealth Toolkit for Quantitative Analysis of Motor Symptoms in Parkinson's Disease

Sritej Padmanabhan

North Allegheny Senior High School, Pittsburgh, PA

Mentor: Dr. Jonathan Tsay, Carnegie Mellon University

Parkinson's disease (PD) affects millions worldwide, impacting motor behavior through tremors, gait abnormalities, and motor learning deficits. Despite its prevalence, the underlying mechanisms of PD-related motor dysfunction remain poorly quantified, limiting our ability to study disease progression and symptom variability. This study introduces ParkinSense, a telehealth behavioral analysis toolkit designed to extract fine-grained motor markers from patient videos and custom games, enabling large-scale, quantitative research into PD behavior. ParkinSense utilizes telehealth-based pose estimation and a motor adaptation game to investigate tremor frequency (Hz), tremor amplitude (mm), gait speed (m/s), and motor learning adaptation curves. These tools were validated on 1,000 simulated tremors and controls, compared to reference accelerometers, stopwatch measurements, and Kinarm machine data. Using data from 200 online participants (100 PD, 100 healthy controls), the system identified distinct tremor frequency bimodal distributions, heightened tremor amplitude asymmetry, and abnormal micro-displacements in fine motor control. Gait analysis revealed shortened step length (38.2 cm vs. 54.7 cm, $p < 0.001$), increased stride variability (11.3% vs. 4.9%, $p < 0.001$), and impaired step timing consistency. Motor learning analysis showed slower adaptation rates ($\beta = -0.41$ vs. -0.58 , $p < 0.001$), increased trial-to-trial variability (4.7° vs. 2.3°, $p < 0.001$), and weaker retention of adaptation (5.2° vs. 12.1°, $p < 0.001$). With over 95% accuracy validated across 1,000 trials for each tool in the toolkit, ParkinSense provides a telehealth framework including a novel quantitative scale for studying PD progression, detecting early motor impairments, and improving long-term patient monitoring.



Philadelphia and Delaware

Lead Contamination is Associated with Decreased Bacillota Species in Soil of Public Parks in Philadelphia

Rishi Amaravadi

Friends' Central School, Wynnewood, PA

Mentors: Marilyn Howarth, Ph.D., Jeffrey Field, Ph.D. and Adrian Wood, University of Pennsylvania, Center of Excellence in Environmental Toxicology; Madeleine Sleeman, University of Pennsylvania, Department of Microbiology

Background: Lead remains a persistent environmental contaminant despite being banned in consumer products. This study examines lead soil contamination in Philadelphia's public parks, examining the impact of lead smelters, vehicle emissions, lead paint, and industrial sources on modern-day soil lead levels and microbiome diversity.

Hypothesis: Public parks near historical lead smelting and roadways will have significantly higher lead concentrations and altered microbiomes than distant control sites.

Methods: Soil samples were collected from three Philadelphia parks at varying distances of historic lead smelting sites and adjacent roadways: Chew Playground (CP), Richmond & Westmoreland Streets (RS), and Vernon Park (VP). 23 soil samples were analyzed for lead via X-ray fluorescence spectroscopy. DNA sequencing of 16S rRNA genes characterized microbial communities, with a microbiome analysis using Epi2me and Phyloseq.

Results: Lead concentrations ranged from 150-700 ppm in RS and VP, exceeding EPA thresholds for children's play areas, while CP had little detectable lead. Principal Component Analysis revealed distinct microbial compositions at RS and VP compared to CP.. Lead-contaminated sites showed depleted Bacillota ($12\% \pm 6\%$ vs. $33\% \pm 9\%$; $P=0.0002$), known for lead remediation.

Conclusion: There was no strong correlation between lead concentrations and distances to the smelting site. However, two out of three sampling sites were found to have higher levels of lead than the EPA threshold. We determined that high lead is associated with a decrease in Bacillota, a phylum that is consistently used to remediate lead in soil. Further sampling is warranted to support bioremediation with Bacillota.

Decoding Drug Resistance: Quantitative Proteomics Reveals Signal Rewiring in Melanoma

Weihan Chen

Conestoga High School, Berwyn, PA

Mentor: Dr. Junfeng Ma, Georgetown University Medical Center, Georgetown Lombardi Comprehensive Cancer Center

Melanoma is an aggressive skin cancer with high metastatic potential and a significant rate of treatment resistance, particularly to targeted therapies such as BRAF and MEK inhibitors. A major contributor to this resistance is signal rewiring, where tumor cells adapt by activating alternative pathways to maintain survival, proliferation, or resistance despite therapeutic pressure. This study employed quantitative proteomics to investigate the molecular mechanisms underlying drug resistance in melanoma cells treated with the combination therapy of trametinib and vemurafenib, specifically investigating which proteins undergo changes in expression and activity that lead to signal rewiring and resistance. Proteomic analysis revealed 2,112 differentially expressed



proteins, with 742 upregulated and 1,370 downregulated in resistant (RES) compared to wild-type (WT) melanoma cells. Key upregulated proteins, including RHBDF2 and PAI2, were implicated in tumor progression and therapy evasion, while downregulated proteins, such as Endoribonuclease YbeY and Nocturnin, suggested disruptions in mitochondrial function and apoptosis regulation. Gene Ontology analysis indicated that resistance mechanisms were associated with cytoskeletal reorganization, metabolic adaptations, and altered cell signaling. These findings highlight critical molecular adaptations that contribute to therapeutic failure and suggest potential targets for overcoming drug resistance. By elucidating the proteomic landscape of resistant melanoma, this study provides insights that may inform the development of novel therapeutic strategies aimed at preventing or reversing signal rewiring. Future research should explore novel combination strategies to preempt adaptive resistance and improve patient outcomes.

BeeMind AI: Development of an Artificial Intelligence-Based System to Assess Honeybee Health, Behavior, and Nutrient Effects

Matthew Lo

The Haverford School, Haverford, PA

Lately, honeybees have been facing increasing population loss due to a collection of environmental issues, including global warming, habitat loss, pesticides, and parasites. To address these issues, this research proposed and built an AI-based honeybee health assessment system called BeeMind AI. The BeeMind AI system integrated eight sensors including temperature and humidity, carbon dioxide, and atmospheric pressure sensors combined with microphone and camera modules. Due to its many functions including the ability to analyze honeybee movement and behavioral patterns, the BeeMind AI system was used to evaluate the effects of four nutrients on honeybee learning and memory through video analysis in two experimental settings, one in a newly designed tri-chambered maze, and another in a free-flying homing paradigm. The free-flying experiment was conducted to study the effect of nutrients on return rates of honeybees at distances of 300 m, 500 m, and 800 m, and it was found that the base return rates of the control group even at 800 m was close to 75%. Additionally, it was observed for the first time that C60 nanoparticles had significant positive effects on honeybee learning, memory, and flying capabilities, improving return rates by around 9% at 300 m, 16% at 500 m, and 20% at 800 m, while neonicotinoid pesticides had negative effects on return rates, reducing them significantly by up to 30%. Combined with the methods and findings achieved in this research, the developed BeeMind AI system demonstrates significant potential for application in the beekeeping industry as a powerful tool.

Optimization of CNGA3 Gene Therapy for Achromatopsia Using Stochastic Modeling and Sensitivity Analysis

Niranjana Sendil Kumar

The Charter School of Wilmington, Wilmington, DE

Teacher: Ms. Toner, The Charter School of Wilmington

Achromatopsia is an inherited retinal degeneration disorder caused by a mutation in the CNGA3 (Cyclic Nucleotide Gated Channel Subunit Alpha 3) gene, affecting every 1 in 30,000 people. Mutations in the CNGA3 cause myopia, nystagmus, and loss of photopic vision. Achromatopsia gene therapy delivers a functional copy of the CNGA3 gene to the affected cone cells using adeno-associated viruses (AAVs). Stochastic models can be used to analyze the randomness in achromatopsia gene therapy, ensuring the ability to configure efficacy by modeling the sensitivities of the delivery efficiency and immune rejection.



The stochastic model was developed to assess the variability of the CNGA3 gene therapy in photopic and scotopic vision. Pycharm, a Python programming software was used to study the stochastic and sensitivity models from the data. Based on the variability from the stochastic models, a sensitivity analysis was used to evaluate the impact of delivery efficiency and immune rejection probabilities on the sensitivity of scotopic and photopic vision.

From the stochastic modeling, it was concluded that photopic vision has higher variability, which revealed that poor delivery efficiency was caused by the immune rejection of the delivery vectors rather than the biological component.

Enhancing the efficiency of CNGA3 gene therapy can be achieved by utilizing immunosuppressive delivery vectors to mitigate vector-related immune responses. Stochastic modeling is valuable in pinpointing critical variables responsible for CNGA3 therapy's success and can help more than 200,000 individuals worldwide benefit from therapeutic CNGA3 gene therapy, enlisting them for absolute freedom.

Assessing immune infiltration and finding potential prognostic factors in acral melanoma on the cell-specific transcriptional level

Angela Wang

Westtown School, West Chester, PA

Acral melanoma (AM) is an aggressive melanoma subtype with high morbidity and mortality, disproportionately affecting individuals of Asian, African, and Hispanic descent. Despite its clinical significance, AM remains understudied due to its rarity and underrepresentation in large-scale studies. Understanding the tumor microenvironment (TME) is crucial for identifying prognostic factors and developing targeted therapies.

This study uses both bulk RNA sequencing (RNA-seq) and single-cell RNA sequencing (scRNA-seq) to assess AM progression. I hypothesize that AM's immune profile is distinct throughout developmental stages, and that novel prognostic markers identified are related to immunosuppressive phenotypes of lymphocytes.

RNA-seq data across four stages of AM progression were analyzed using GO and KEGG enrichment analyses, revealing that early-stage tumorigenesis is associated with cell proliferation and immune activation, while later stages involve extracellular matrix remodeling and apoptotic pathways. TIMER analysis indicated a higher abundance of B cells, CD4+ T cells, and NK cells in early-stage AM, whereas CD8+ T cells and M2 macrophages dominated later stages. ScRNA-seq data were clustered and annotated to identify immune cell subtypes involved in AM progression. Survival analysis using the TCGA dataset identified potential immunoprognotic markers. FANK1 was linked to regulatory T cells, suggesting a role in immunosuppression, while TP53INP1 was associated with B-cell differentiation, and USP3 showed correlations with Th17 cells and NK cells. Further experimental validation can be performed with these prognostic markers in AM progression.



Puerto Rico

Photodynamic Therapy Based on Protoporphyrin IX-loaded Boron Nitride Nanotubes as Photosensitizing Solutions to Induce Apoptosis in A375 Cells

Gianna I. Ríos García

Specialized School in Science and Mathematics Dr. Pedro Albizu Campos, Ponce, Puerto Rico

Teacher: Mr. Jonatan Plaza Plaza

Mentor: Dr. Angel Martí Arbona

Due to the lack of minimally invasive and selective treatments for melanoma, the effectiveness of photodynamic therapy (PDT) based on boron nitride nanotubes (BNNT) loaded with Protoporphyrin IX (PpIX) was evaluated to increase intracellular accumulation of the photosensitizer and induce apoptosis in A375 cells. PpIX, a porphyrinoid derivative precursor to the 5-ALA metabolism, induces cell death in neoplastic cells. Therefore, it was established that if BNNT retain their ability to load drugs and PpIX is activated through irradiation, the photosensitizer will accumulate intracellularly, and PDT will induce apoptosis in A375 cells. In this in-vitro study, A375 cells were treated with PDT based on PpIX and BNNT+PpIX at 20%. PDT showed effectiveness in reducing cell viability in an MTT assay, while cells treated with the compounds without irradiation showed higher viability. The interaction of PpIX with BNNT facilitated intracellular localization, with ~60-70% colocalization in the cells, mostly in the mitochondrial region. Singlet oxygen (1O_2), generated by the activation of PpIX under irradiation (QYs = 26%), induced apoptosis, as evidenced by Annexin V (+) cytometric detection and the absence of PI (-), with no significant signs of necrosis. This means that specifically, the integration of nanotubes in the treatment caused the photosensitizer to accumulate successfully in the mitochondrial region, which triggered the activation of the apoptotic pathway, so the hypothesis was accepted. A T-test found a statistically significant difference between both PDT treatments compared to treatments without irradiation (p value=0.001/ confidence interval 99.9% and p value=0.01/ confidence interval 99%).

A Comprehensive Study of Ionized and Molecular Gas in M42A and M42B

Daniela Méndez Cora

Escuela Especializada en Ciencias y Matemáticas Genaro Cautiño, Guayama, Puerto Rico

Mentors: Haydee Laporte and Dr. Allison Smith

This project is a study on molecular and ionized gas in a well-known star forming region, M42A and M42B (Orion Nebula). H_2 (molecular hydrogen) is the most common molecule in space, but it's very difficult to detect. For years, scientists have used CO (carbon monoxide) to search for H_2 . The problem with CO is that it can only detect H_2 in high densities. CH (methylidyne) is another well-known proxy for molecular hydrogen, which is difficult to detect directly, but can find H_2 in low densities. The research question was: "Is there detectable ionized hydrogen and H_2 in M42A and M42B?" and the hypothesis was "If we observe CH in M42A and M42B, then it will help us assess the abundance of H_2 and observing H RRLs will help us assess the presence of ionized hydrogen gas." In July 2023 the CH was observed in 3.3 GHz lines using the 12-m radio telescope at the former Arecibo Observatory site. The observations were obtained using an ON-OFF method. All the radio telescope data on M42A and M42B were combined using a pipeline of Python programs, correcting for the Earth's velocity toward these objects, and baselining the spectrum. Then the characteristics of any CH and H RRL detections were obtained using a gaussian fitting routine. After a series of calculations, we were finally able to obtain the amount of molecular hydrogen in M42A and M42B. We concluded that our hypothesis was accepted as we found signals for both ionized hydrogen and H_2 .



Temporary inhibition of *Polo Like Kinase-1* using the siRNA technique in triple-negative breast cancer cells to reduce the expression of mesenchymal markers

Paula S. Méndez Torres

Dr. Pedro Albizu Campos Specialized School in Science and Math, Ponce, Puerto Rico

Mentors: Dr. Harold Saavedra, Ph.D., Kathia Y. Rodríguez Negrón, M.S., and Melanie Cruz Robles, B.S.

In 2022, 2.3 million cases of breast cancer were diagnosed worldwide; approximately 17% were classified as triple-negative breast cancer (TNBC). TNBC is difficult to mitigate due to the absence of estrogen, progesterone, and HER2 receptors. Studies reveal ethnic disparities between non-Hispanic white (NHW) and Black women (NHB) with the MDA-MB-231 and MDA-MB-157 cell lines. Overexpression of *Polo Like Kinase-1* (*PLK-1*), a mitotic kinase of G2 and M phases, can lead to uncontrolled proliferation and treatment resistance. This project hypothesizes that if *PLK-1* is temporarily inhibited using the siRNA technique in TNBC, it will reduce the expression of epithelial-mesenchymal transition (EMT) markers: Vimentin, N-cadherin, β -catenin, and E-cadherin. Each biomarker has one hypothesis for NHB-derived cells and another for NHW-derived cells. The cells were transfected with siRNA for 48hrs. RNA was converted into complementary DNA for RT-PCR analysis, and proteins were used for the Western blot. T-test results from RT-PCR showed a significantly reduced expression of *PLK-1* in both cell lines using siRNA. NHB-derived cells had a p-value of 0.009, while NHW-derived cells had a p-value of 0.0152. In the experimental group, E-cadherin expression showed an increasing trend in MDA-MB-157, while Vimentin expression showed a decreasing trend in MDA-MB-231. To corroborate results, Western blot showed statistically significant inhibition of *PLK-1* in both cell lines. It also showed a trend of increased β -catenin in MDA-MB-157. These findings support hypotheses H_1 , H_7 , and H_8 , suggesting that si*PLK-1* is a promising strategy for reducing mesenchymal markers in TNBC and transitioning cells into a benign state.

Phytochemical Intervention for Neuroinflammation in Modulating Macrophage Dynamics at the Blood-Brain-Barrier

Lorena Pachiarri

Cupeyville School, San Juan, Puerto Rico

Mentors: Dr. Antonio H Martins and Dr. Yancy Ferrer

Chronic neuroinflammation and the migration of macrophages to the blood-brain barrier (BBB) are significant characteristics of various neurological diseases. In this context, the adhesion of macrophages plays a crucial role in immune responses. However, long-term anti-inflammatory treatments can lead to serious side effects, such as osteoporosis and cardiovascular problems. This study aims to explore phytochemical alternatives, focusing on quercetin derived from soursop, as a potential inhibitor of macrophage adhesion in brain endothelial cells. Although the peripheral anti-inflammatory effects of quercetin are well-established, its influence on macrophage adhesion within the neurovascular unit is not yet fully understood. We hypothesize that quercetin will modulate macrophage adhesion on brain endothelial cells. To investigate this, we used RAW 264.7 macrophages together with bEnd.3 brain endothelial cells. Inflammation in the bEnd.3 cells were induced using 100 ng/ml of lipopolysaccharide (LPS), followed by treatment with 5 μ M quercetin for 48 hours. A fluorescence-based adhesion assay was employed to quantify the attachment of macrophages. The results indicated that 5 μ M quercetin did not decrease macrophage adhesion under inflammatory conditions. In contrast, 50 μ M dexamethasone resulted in a notable decrease in adhesion. These findings imply that quercetin does not modify the binding of BBB endothelial cells to macrophages during inflammation. Future studies will focus on the direct effects of quercetin on macrophages to further evaluate its impact on adhesion. This



research contributes to a deeper understanding of how phytochemicals can affect inflammation-related cellular functions.

Artificial Intelligence Models to Simulate and Assess the Viral Expansion of Influenza A/ H5N1 Cattle Outbreak

Sriniketan Sridhar

Southwestern Educational Society, Mayaguez, Puerto Rico

H5N1 Avian influenza Bird Flu is an infectious disease that has implications for the human health and global economy. Recent infections have spread across the United States, forcing farmers to kill their livestock of ducks and hens, leading to an increase in egg prices. H5N1 is most common with cattle, B3.13 as recent human infections have been seen to be directly linked with cattle.

Artificial Intelligence (AI) based approaches are developed to simulate the expansion of B3.13 viral DNA sequences. The pre-trained Generative Pretrained Transformer (GPT-2) which is a Natural Language Processing (NLP), Large Language Model (LLM) has been adapted to generate new B3.13 DNA viral sequences. A second AI Deep Learning (DL) model called the LSTM (Long Short-Term Memory) which uses long short-term dependencies has been used to generate new B3.13 DNA viral sequences. 1300 evolutions and 225 evolutions have been simulated using Transformer and LSTM, respectively. The new evolved B3.13 cattle virus sequences were evaluated using Convolutional Neural Network (CNN) by classification of the simulated sequences against other Mammal genotype H5N1 A/Influenza original viral sequences.

The assessment demonstrated that both Transformer and LSTM were efficient at predicting new expansions of H5N1 B3.13 cattle outbreak virus sequences with a classification accuracy of 96.2% for transformer and 70.8% for LSTM for 5 genotypes. The transformer shows a better performance in simulation than LSTM model. Five-fold cross validation was done to test the CNN model.

South Carolina

The Effect of Indole-3-Carbinol on *Saccharomyces cerevisiae* Growth, as a Model for Cancer Cells

Sadhana Anchoori

Spring Valley High School, Columbia, SC

Teacher: Heather Alexander, Clemson University & University of South Carolina

Extensive research has explored cancer cell growth and potential treatments. However, the effects of different concentrations of indole-3-carbinol (I3C) on cancer cell growth remain unclear. This study aimed to determine whether the concentrations of indole-3-carbinol would impact the growth of *Saccharomyces cerevisiae*. These findings may have implications for cancer prevention as *S. cerevisiae* and cancer cells exhibit similar growth properties. It was hypothesized that the higher concentrations of I3C would exhibit more antifungal properties based on previous research showing that I3C tends to shut down harmful pathways, such as the Kennedy pathway. This hypothesis was tested using the following concentrations of indole-3-carbinol: 50%, 80%, and 100%, with 100% being a 2.5 g I3C solution. Zone of inhibition disks, soaked in different I3C concentrations, were placed on *S. cerevisiae* streaked petri dishes. The amount of antifungal activity (in mm) was recorded. The results from the ANOVA test with an alpha value of .05 showed that there were significant differences between the experimental groups and the control ($F(3, 116) = 117.36, p < .0001$). A post hoc Tukey test was performed and it was found that there were



significant differences between each experimental group. It was concluded that there was sufficient evidence to suggest that higher concentrations of I3C led to more antifungal activity against *S. cerevisiae* compared to the lower concentrations.

Understanding Changes in Sound Intensity Level for Masking Configurations Used to Prevent Respiratory Illnesses

Max Berg

Spring Valley High School, Columbia, SC

Teacher: Dr. Michelle Spigner, Spring Valley High School

Face masks are common for preventing the spread of respiratory illnesses, with immunocompromised individuals commonly wearing one mask or more to improve protection against airborne particles. Previous research has noted communication issues with masks due to natural acoustics caused by their intrinsic properties. The goal of this study was to understand changes in sound intensity level (dB) from different masking configurations (single and double surgical mask, surgical mask with cloth mask, surgical mask with N95 mask) at frequencies of vowel formants (peaks in amplitude of the human voice that define tone). It was hypothesized that at all three frequencies (280, 1030 and 1920 Hz), the cloth mask with surgical mask would have the lowest sound intensity level. To test this, a model head was utilized with a speaker and microphone, and the sound intensity level was recorded using the Praat software. A two-way ANOVA test showed the interaction between masking configuration and frequency to have a significant impact on the sound intensity level, $F(6, 348) = 393.23$, $p < .001$. Simple main effects tests revealed that both masking configuration and frequency significantly affected the sound intensity level, $p < .001$ for both tests. It was concluded, therefore, that the masking configurations utilized in the study led to significant decreases in sound intensity level compared to a single surgical mask. The hypothesis was not supported by the collected data, as the cloth mask with surgical mask did not have the lowest sound intensity level for two of the frequencies.

Design of a Low-Cost Phone-Based Fluorescence Microscope Incorporating the Photoacoustic Effect to Modify Fluorescence of Planarian Toxicity Fluorescent Assay-Induced *Dugesia tigrina*

Srianeesh Kalva

Spring Valley High School, Columbia, SC

Teacher: Dr. Michelle Spigner

Fluorescence microscopes are pivotal components of scientific research. However, high costs and photobleaching of specimens over long exposure periods hinder scientific progress, producing malignant data and limiting research accessibility. This research aimed to solve these issues by designing a phone-based fluorescence microscope incorporating the photoacoustic effect. This effect states that tissue exposed to pulsed light absorbs the light's energy, rises in temperature, thermally expands, and produces acoustic waves. This approach was taken because a smartphone dramatically reduces the cost of the device and the photoacoustic effect's expansion may improve specimen fluorescence. This device consisted of a 3D printed frame and parts, an objective lens, tube lens, and breadboard circuit with LED lights and an Arduino Uno. The prototype was tested using *Dugesia tigrina* by calculating each specimen's corrected total cell fluorescence (CTCF) when treated with a planarian toxicity fluorescence assay. This assay was performed by exposing organisms to an antiseptic solution, then to the fluorescent dye sodium fluorescein, and then viewing them under the prototype before and after a five-minute period with and without the photoacoustic effect. It was found that the prototype achieved its goal by preventing photobleaching, but a two-way repeated measures ANOVA reported that the presence of the photoacoustic effect, photobleaching, and their interaction had no significant



effect on CTCF at an alpha value of 0.05 ($F(1,29) = [2.427]$, $F(1,29) = [.020]$, $F(1,29) = [.954]$). However, the η_p^2 of the photoacoustic effect revealed that this played a moderate role in data variance.

The Use of Metabolomics with Regards to Hypothyroidism and Potential Applications in Treatment and Diagnosis: A Meta-analysis

Morgan Kay

Riverside High School, Greer, SC

This study hoped to shed light on the use of metabolomics to identify biomarkers of hypothyroidism. Thus, the review focused on compiling data that correlates metabolites with hypothyroidism to determine how metabolites differ between euthyroid and hypothyroid states. It was hypothesized strong correlations would be shown between some metabolites and hypothyroidism, denoting them as biomarkers that could be used in diagnosis and treatment. A total of nine studies were included and 291 metabolites were identified. The included articles represented several populations, with studies taking place in Europe, China, and Egypt. Almost all studies had a robust sample size and focused on different groups of metabolites, which helps paint a broader picture of the whole metabolism. Ultimately, one of the studies skewed results toward a strong positive correlation, and thus synthesis results were presented including and excluding this study. When excluded, the mean odds ratio was 1.533, which indicates a very weak positive association. This means that most metabolites do not show significant changes between hypothyroidism and euthyroid states; however, some individual metabolites showed significant changes and are thus biomarkers that could be used to improve the treatment and diagnosis of hypothyroidism. It is imperative further research be conducted utilizing metabolomics in conjunction with hypothyroidism to identify more biomarkers. Moreover, future research might couple these findings with machine learning to craft prediction models, simplifying diagnosis and treatment plans. Additionally, metabolomics might provide insight as to why hypothyroidism symptoms persist after normal thyroid hormone levels have been reached.

In Vitro Model for Cigarette Smoke-Induced Intervertebral Disc Degeneration

Yiqing Ye

Academic Magnet High School, North Charleston, SC

Mentor: Prof. Yongren Wu, Medical University of South Carolina

Low back pain affects 80% of individuals over 50 and is increasingly prevalent among younger adults aged 18–29. It is strongly associated with lumbar intervertebral disc (IVD) degeneration, a condition with no existing cure. Cigarette smoking, practiced by 11.6% of the U.S. population, is a major risk factor, yet the mechanisms underlying smoking-induced IVD degeneration remain poorly understood. To address this gap, this study established an *in vitro* IVD organ culture system to investigate the effects of cigarette smoke extract (CSE) on disc cell function and assess the protective potential of the antioxidant N-acetyl-L-cysteine (NAC). The hypothesis was that CSE-induced oxidative stress drives IVD cell damage, with NAC mitigating these effects by reducing oxidative stress, restoring cell function, and providing region-specific protection. A syringe-based smoking apparatus was adapted to generate CSE, with optical density and nitrite content analysis confirming its quality. Organ cell viability was validated through fluorescent staining. Exposure to 10% CSE increased oxidative stress (reactive oxygen species levels), calcification (alkaline phosphatase activity), and apoptosis (caspase-3 activation), with the greatest damage observed in cartilage endplate (CEP), the disc-bone interface. NAC treatment significantly reduced these effects, preserving cell function. These findings establish oxidative stress as a primary mechanism of CSE-induced IVD degeneration and highlight the CEP as a critical target for early diagnosis and therapeutic intervention. By demonstrating NAC's potential in mitigating CSE-induced



damage, this study lays the foundation for future research, including animal models and clinical trials, to develop pharmacological strategies to preserve disc integrity and function.

Southwest

Parks: Assessing How Urban Green Spaces Affect Youth Well-being

Sofia Peinado

Harmony Science Academy, El Paso, TX

This project examines how access to urban green spaces affects the health and well-being of youth aged 5-16. The goal is to determine if these spaces help reduce stress, encourage physical activity, and improve social interactions. Participants were divided into two groups: those with regular access to green spaces and those without. Data was collected through surveys measuring stress and happiness levels and direct observations of physical activity and social behaviors in green and non-green areas. Preliminary findings show that youth with access to green spaces report lower stress levels, higher happiness scores, and more frequent social interactions. They also engage in more physical activities during observations compared to those without access. These results confirm that green spaces contribute positively to both mental and physical health. The study concludes that urban green spaces are essential for supporting the well-being of children and teenagers. The results can guide policymakers to prioritize adding parks and recreational areas, especially in underserved communities. Expanding access to these spaces could help reduce health disparities and create healthier environments for children. Future research could explore how specific green space features, like playgrounds or sports fields, enhance benefits or assess the long-term impact on youth development. This study underscores the importance of integrating nature into urban planning to support the health and happiness of younger populations.

Soap Wars: Antimicrobial vs. Regular Soap

Sarah Perales

Harmony Science Academy at El Paso, Tx

Teacher: Ms. Anais Vazquez

Eighty percent of all infections are transmitted through touch, but we can avoid most of them by simply washing our hands the proper way. Antimicrobial resistance is a widespread issue growing more and more overtime. Many diseases evolve from antibiotic resistance and one common way it can occur is through the process of washing hands. The project will explore if antimicrobial soap is used, the greater the chance of promoting resistant bacteria. Overall, the experiment will dive into the effectiveness of antimicrobial soap on bacteria and how this will be an issue in the long run.

The results of the experiment showed very to no little data due to insufficient incubation time (less than the recommended 24–48 hours), bacterial growth was minimal, leading to inconclusive results. Consequently, the expected zones of inhibition could not be accurately measured. These limitations highlight the importance of proper experimental conditions in evaluating soap efficacy. Although the experiment did not yield definitive results, the study underscores the ongoing concern of antimicrobial resistance and the need for further research to distinguish the long-term impacts of antimicrobial versus regular soap on bacterial populations.



The Effect of Red 40 in Our Body by Consumption: A Vicious Cycle for Our Generation

Dayra Realzola

Harmony Science Academy, El Paso, TX

The purpose of this experiment is to analyze whether consuming chips, a popular snack eaten by many daily, can impact blood pressure. This is particularly important because these chips often contain Red 40, a food dye that has been linked to potential health issues. There have been reports of adolescents being hospitalized due to Red 40, which is thought to contribute to problems like high blood pressure and even cancer.

The results of the experiment varied among the participants. For four of them, blood pressure actually decreased after consuming the chips. In a few others, there was no change at all. However, one participant experienced an increase in blood pressure after eating the chips.

These findings suggest that Red 40, present in these popular snacks, may affect blood pressure differently for each individual. While some participants showed no harmful effects, the increase observed in one case highlights potential risks, especially for teenagers and adolescents. Further research is needed to understand the long-term effects and the specific role Red 40 may play in these outcomes.

Preventing Shock Wave Induced Brain Injury Using Materials and Structures

Anderson Stoker

Albuquerque Institute of Math and Science, Albuquerque, NM

This research is focused on determining which of multiple common and accessible shock absorbing materials and structures is the most effective at mitigating the force of a shock wave, materials like Sorbothane, polyurethane, silicone, Neoprene, and Neoprene foam. It was hypothesized that Sorbothane would be the most effective. Two common materials used in current military gear, carbon fiber and steel, were tested along with the shock absorbing materials. The shock wave required for this experiment was generated using a vacuum cannon, which uses vacuum pressure to accelerate lightweight projectiles. This device was able to reach speeds of mach 1.2 consistently. The data was measured using the force detected by the piezo microphone behind the sample material compared to the force detected by the piezo microphone in the open. The results show that steel is the most effective shock mitigating material. Sorbothane is the second most effective material. When taking mass into account, Neoprene foam mitigated the largest amount of a shock wave per gram by a very large amount at blocking 32.1% of the shock wave per gram. Polyurethane was the second most effective material by mass at 4.9% per gram. As a secondary piece of this experiment, several 3D printed polyurethane structures were also tested using the same methods. Of these structures, straight ridges, curved ridges, and fins, the fins were the most effective by mass, blocking 7.7% per gram, being more effective than the solid polyurethane.



ICEFAB-Nano: An Integrated Computational-Experimental Framework to Accelerate the Development of Highly Biofunctional Nanotherapeutics for Healthy and Cancerous Applications

Aarush Tutiki

Albuquerque Academy, Albuquerque, NM

Mentor: Achraf Nouredine, University of New Mexico

The rational design of biofunctional nanomaterial (NM)-therapeutics is hindered by limited predictive tools, particularly regarding microenvironment-modulated release, *in vitro* to *in vivo* cytotoxicity in both cancerous and healthy cells, and biodistribution across organs and tumors. To address these challenges, *ICEFAB-Nano* emerges as first-in-class *in silico* platform built upon the largest NM-Quantitative Structure Activity Relationship (QSAR) datasets for seven targeted functions, yielding >14,000 previously unextracted datapoints. Each *in vitro* QSAR dataset incorporates 27 descriptors spanning macro-scale (size, shape, zeta potential, etc.) and molecular-scale features extracted via RDKit. Descriptors trained numerous off-the-shelf and custom Machine Learning models, while regression models were integrated with Physiologically Based Pharmacokinetic Modeling for *in vivo* predictions. A SHapley Additive exPlanations (SHAP)-based iterative reduction pipeline was employed to rank features and identify those most critical. The best-performing models for each function were subsequently integrated to create *ICEFAB-Nano*, which demonstrated robust validation on both internal and externally curated test sets.

Furthermore, *ICEFAB-Nano* mined an experimental library of >600 known NM formulations originally designed for diverse applications to pinpoint NMs optimized for specific therapeutic goals. For validation, it selected Silica NMs for doxorubicin and paclitaxel chemotherapeutic delivery to ovarian cancer cells and Lipid NMs for GFP siRNA nucleic acid delivery to healthy kidney cells. Eleven candidates, chosen via Cluster Analysis, exhibited strong *in vitro* performance. *ICEFAB-Nano*'s SHAP explainability pipeline yielded translatable, testable hypotheses, including a first-case finding that charge dispersion in highly positive NM surface coatings can shield healthy cells from toxicity while preserving NM functionality.

Tennessee

Identifying Key Factors to Improve Autism Spectrum Disorder Diagnosis with Machine Learning

Brandon Bonamarte

Oak Ridge High School, Oak Ridge, TN

Mentor: Rick Archibald, Oak Ridge National Lab

Autism Spectrum Disorder (ASD) is a neurological disorder characterized by significant social, communication, and behavioral challenges. Current diagnostic practices typically involve a multi-step process, beginning with an initial screening followed by assessments such as the Social Responsiveness Scale (SRS) to evaluate the severity of ASD. Challenges with the current approach include diagnostic delay, potential inaccuracies, and higher costs, which can delay diagnosis and treatment. Machine learning has the potential to streamline the diagnostic process by employing statistical algorithms to analyze and predict patterns in ASD patient data. The Autism Brain Imaging Data Exchange (ABIDE) is a collaborative database that compiles autistic and allistic brain images and patient data from numerous scientific and educational institutions. The data from ABIDE includes: sex, handedness, age at brain scan, SRS total raw score, SRS raw subscores, SRS adjusted score, SRS adjusted subscores, and SRS edition. SRS subscores include mannerisms, awareness, communication, cognition, and motivation. ABIDE patient data



was used to train k Nearest Neighbor machine learning algorithms to predict ASD. Results showed that not only can SRS predict ASD, but also that subsets of the total SRS score can be omitted while maintaining high accuracies in ASD diagnosis predictions.

Electrospinning Tissue Scaffolds for the Annulus Fibrosus

Kim Huang

St. Mary's Episcopal School, Memphis, TN

Teacher: Dr. Anna Bess Sorin, St. Mary's Episcopal School

Back pain affects millions of people in the United States every year, often resulting from damaged or degenerated intervertebral discs. Current surgical treatments, including discectomies, spinal fusions, and metal total disc replacements, frequently lead to painful, long-term complications like nerve damage, limited range of movement, and the repeated need to undergo surgery. This study hypothesizes that electrospun scaffolds composed of a synthetic blend of biopolymers can effectively replicate the structure of an intervertebral disc and serve as a scaffold for cell seeding. Given electrospinning's unique ability to produce highly aligned fibers, this method can closely replicate the body's native intervertebral disc architecture as a biomimetic alternative to traditional intervertebral disc replacements. A synthetic blend of biopolymers, including polycaprolactone and poly-lactic acid, was developed to mimic the mechanical structure of the annulus fibrosus. A rotating mandrel electrospinner was used to successfully achieve 3D circular lamellar structures with fibers assembled at the 30° to horizontal orientation that gives these disks their strength and flexibility. The scalable nature of mandrel electrospinning presents a more cost and time-effective approach than other current solutions, potentially enabling rapid production of cervical, thoracic, and lumbar intervertebral disc scaffolds. These findings suggest a feasible way to develop electrospun intervertebral discs as a reliable, biologically compatible solution that could reduce complications and improve quality of life for individuals struggling with back pain.

Accelerating Scanning Probe Microscopy Using Sparse Reconstruction Algorithms

Langalibalele Lunga

Farragut High School, Knoxville, TN

Mentors: Rama K. Vasudevan, Anthony Cabrera, Narsingha R. Miniskar, and S.V.

Venkatakrishnan, Oak Ridge National Laboratory (ORNL)

Scanning Probe Microscopy uses a sharp probe to scan a material's surface in a zig-zag raster pattern. Though highly accurate, raster scans can be slow and inefficient, limiting the study of surface changes over time. While previous research has used methods such as Gaussian Process Optimization and Compressed Sensing, few studies have addressed the combination of baseline sparse reconstruction methods and deep learning for scanning acceleration. Our study addresses this gap by utilizing biharmonic inpainting and Convolutional Neural Networks on varying sparsity levels that model different scanning speeds, with our experiments showing significant results. Our biharmonic inpainting approach, the baseline method, had a max average testing error of ~7%, while our deep learning approach showcased a max average error of ~4%. These performance metrics, along with further out of distribution studies conducted in our research, highlight that our deep learning approach can be highly effective compared to previous baseline methods of image reconstruction. By showing a decrease in error compared to baseline methods, our study offers a newer approach to accelerating scanning probe microscopy through deep learning techniques.



SpineSync: Enabling Self-Tracking of Parkinson's Disease Progression Through an IMU-Embedded Wearable Device

Rohan Ramachandran

University School of Nashville, Nashville TN

Mentor: Dr. Richa Misra, Vanderbilt University

Parkinson's disease (PD) is the second most common neurodegenerative disorder, affecting ~10,000,000 people worldwide. 86% of PD patients suffer from kyphosis, or curvature of the thoracic spine. Unlike an HbA1C test for diabetes or a lipid panel for cholesterol, PD patients lack similarly objective tools for tracking kyphosis, a proxy for progression of PD. Calculation of the Cobb angle using x-rays is the most accepted kyphosis quantification method, but high cost, radiation exposure, procedural error, and low patient compliance hinder clinical adoption. In this work, we propose a noninvasive, IMU-embedded, wearable neoprene device to enable self-guided kyphosis tracking and spine visualization. Performance was validated by testing the device on 20 kyphotic spinal positions (trials) using an anatomically-accurate skeleton, half directly on the spine, and the other half conducted by adding an interstitial layer simulating human flesh. In each trial, we classified the difference between the Cobb angle as measured by the device and calculated through a photograph as the Cobb error (CE). The mean Cobb error was found to be 2.295 degrees (95% CI 1.17-3.425). Following a One Sample T Test (interobserver radiograph error= 3.3°, H_0 : CE = 3.3°, H_a < 3.3°, $p < 0.037$), we rejected H_0 , concluding that the device accurately tracks kyphosis and quantifies PD progression, more so than a radiograph when including interobserver error. Applications include military rehabilitation tracking, gauging efficacy of physical or pharmaceutical therapy, quantification of employee workload in industries using physical labor, and motion tracking in athletics.

Towards the Treatment of Neuropsychiatric Disorders: The Impact of Amphetamine on the Dopamine System in Relation to Ovarian Hormone Cycles

Lin Zheng

University School of Nashville, Nashville, TN

Mentor: Dr. Erin Calipari, Vanderbilt University

Amphetamine is a psychostimulant that is widely prescribed for neuropsychiatric disorders, including attention deficit hyperactivity disorder (ADHD), due to its ability in enhancing striatal dopamine processing. Biological sex critically affects this process as sex differences in both basal and stimulant-induced processes influence the expression and treatment of ADHD symptoms. This project aimed to elucidate the mechanism underlying this process and test the hypothesis that circulating ovarian hormones in females enhance basal dopamine activity, leading to increased stimulant efficacy. Using ex-vivo fast scan cyclic voltammetry, I investigated sex differences in dopamine release and clearance in rodent striatal brain slices at baseline and with increasing doses of amphetamine. To monitor ovarian sex hormone effects on dopamine processing, female rodents were categorized by their estrous cycle stage. Dopamine measurements were taken in males, females in proestrus/estrus when estradiol levels are highest, and females in metestrus/diestrus when estradiol levels are low and comparable to males. When the data were separated by biological sex, baseline dopamine release and clearance were sensitive to ovarian hormone cycle and enhanced in proestrus/estrus females. Additionally, amphetamine's effects at the dopamine transporter (DAT), which mediates dopamine clearance, was highly sensitive to ovarian hormone cycle and further enhanced in proestrus/estrus females. The results of these studies provide valuable mechanistic insights into the sex differences observed in response to stimulant medications, suggesting there may be larger implications in how these medications are prescribed to women for treatment of many neuropsychiatric disorders, such as ADHD.



Texas

Chemical Modification of Acetaminophen to Reduce Liver Toxicity and Enhance Drug Efficacy

Chloe Yehwon Lee

Plano East Senior High School, Plano, TX

Mentor: Junha Jeon, University of Texas at Arlington

Acetaminophen is a widely used non-opioid analgesic and antipyretic medication. Unfortunately, its toxicity is a leading cause of liver transplantation worldwide. NAPQI, the toxic form of acetaminophen produced after oxidizing in the body, is an electrophile that depletes glutathione and eventually attacks liver proteins, which are nucleophilic. Existing approaches to acetaminophen modification to decrease toxicity are impractical as they modify functional groups necessary for acetaminophen's analgesic properties. Thus, this research aims to reduce toxicity without sacrificing the drug's efficacy by modifying acetaminophen's benzene ring structure. It was hypothesized that sequential transition metal catalysis, involving precise C-H silylation of acetaminophen, followed by the nucleophilic addition of an alkyne to the silicon center, could decrease acetaminophen toxicity while maintaining its therapeutic effectiveness.

The lowest unoccupied molecular orbital (LUMO) energy values of acetaminophen analogues were computed through *Orca 5.0* and retrieved in *Avogadro* to assess toxicity. Docking simulations were then performed through *AutoDock Vina* to analyze the efficacy of acetaminophen analogues by evaluating their binding to transient receptor potential vanilloid 1 (TRPV1). An original scheme was developed and optimized to synthesize 2-phenylalkynylsilyl acetaminophen.

All acetaminophen analogues had higher LUMO energies than the original compound, indicating reduced nucleophilic reactivity and decreased liver toxicity. They also exhibited enhanced binding to TRPV1, demonstrating improved analgesic efficacy. 2-phenylalkynylsilyl acetaminophen was synthesized through precise C-H silylation via sequential transition metal catalysis, followed by nucleophilic addition of an alkyne. The research further suggests a previously unknown mechanism of transition metal catalyst chemoselectivity.

A Biologically-Inspired Quantum Machine Learning Algorithm

Sanskriti Manoharan

Hightower Highschool, Missouri City, TX

Mentor: Heiko Neumann, Ulm University

The biological brain is the most efficient computer in existence, performing 10^{18} operations per second using only 20 watts of power. State-of-the-art machine learning lags exponentially behind in energy efficiency, optimal coding, and robustness compared to biological systems of similar scale. This project constructed a biologically-inspired machine-learning vision model that mimics the behavior of specific biological neural circuits, to improve model performance and efficiency.

This project hypothesizes that a quantum approach will more aptly mimic biological behaviors and demonstrate increased benefits due to intrinsic quantum properties such as the global quantum entanglement for feature extraction and increased parallelization.

The proposed model is comprised of two units. The first unit models simple and complex cells for preprocessing, and the second unit extracts abstract, global features of the image using a



quantum kernel convolution, whose weights are trained with an Adam optimizer and cross-entropy loss function.

The proposed model was compared to classical CNN and biological models. Models were trained on MNIST and Fashion-MNIST datasets.

To test the similarity of the models to biological networks, they were presented with novel image distortions, such as noise, contrast modulations, adversarial attacks, and shape-vs-texture bias. Due to the high adaptability and robustness of the human visual system, augmented images are easily recognizable by human observers, but historically difficult for machine learning models.

When tested, all models achieved similar raw accuracy, but the proposed quantum model surpasses other models in robustness and energy efficiency. This project concludes that quantum properties hold promise for biologically-inspired machine learning.

Year 3: A Novel Water Filtration System Using Nano-Particle Enhanced *Moringa oleifera* and Coconut Shell-Activated Carbon

Satvika Nadella

Allen High School, Allen, TX

According to the U.S. E.P.A., wastewater treatment facilities process approximately 34 billion gallons of wastewater daily. Once filtered, wastewater is released into local water sources despite containing levels of nitrogen and phosphate. Greywater is a common wastewater type produced from households that includes types of soapwater. Nanoparticles have been recently studied as a new source of treatment for wastewater and propose an efficient method of filtration to efficiently purify heavily contaminated wastewater.

This study aims to refine the previously established ability of the two-stage Moringa Seed and Coconut Shell-Activated Carbon (CSAC) Filter. By incorporating MgO nanoparticles into the system, we aim to enhance the moringa seed's natural antibiotic effect to accelerate the filtration process.

The two-stage testing process began with testing various MgO concentrations (25%, 50%, 75%) in the moringa pod to determine the optimal purification of lead, copper powder, ammonium nitrate, and phosphate, in simulated water. Results demonstrated 50% MgO allowing for complete removal of contaminants, which led to its use in subsequent testing. Stage 2 of testing incorporated MgO within the Moringa Seed and CSAC filter. This enhanced system was tested using greywater, and results demonstrated 100% elimination of contaminants and no observable bacterial growth over five days. *Daphnia magna* were also observed in the filtered water, and the heart rates were stable at 276 bpm, determining the water to be non-toxic.

This novel, Nanoparticle-enhanced *Moringa oleifera* and Coconut Shell-Activated Carbon Filter is proven to be a low-cost, effective greywater filtration system applicable for global use.



Vocalyze: A Deep Learning Approach to Detecting Major Depressive Disorder (MDD) and Tracking Treatment Efficacy via Vocal Acoustic Inflections and Sentiment Analysis

Siri Peddinti

Plano East Senior High School, Plano, TX

Sponsor: Julie Baker

Major depressive disorder (MDD) stands as one of the most prevalent and perilous mental health conditions globally. Nearly sixty percent of individuals who have lost their lives to suicide display symptoms of MDD. However, current diagnostic measures rely heavily on doctor evaluations or ambiguous, non-standardized surveys, lacking biomarker analysis. Furthermore, treatment evaluations occur sporadically, with little effective monitoring in most cases. However, MDD presence and severity can be identified and tracked by analyzing vocal prosodic features, and contextual semantic analysis of spoken words. Efficient diagnosis and monitoring of MDD is achievable through Vocalyze, a user-friendly portal. Patients provide a vocal response to a provided prompt to diagnose MDD and later provide daily responses in the Vocalyze UI to assess treatment efficacy. The system is built on two models. Model 1 is a convolutional neural network that provides a diagnosis and predicts PHQ-9 scores based on vocal prosodic features. This model was trained with 187, 276 data sets, tested with 46,819 data sets, and produces a diagnosis accuracy of 98% and a r-squared score of 0.921 between predicted and ground truth PHQ-9 scores. Model 2 is a natural language processing model and performs sentiment analysis to analyze transcripts of the daily recordings, consistently producing a confidence level for each sentiment over 5%. Vocalyze, through effective analysis of vocal prosodic biomarkers possesses an accuracy rate surpassing current methods by over 40%. This system is an accurate, accessible, and cost-effective alternative, countering current dangerous practices contributing to alarmingly elevated suicide rates.

The Salt to My Pepper: Utilizing the Bioactive Descriptors of Piperoyl Piperidine on *Drosophila Melanogaster* as a Neoteric Treatment for Breast Cancer

Diya Shah

Plano East Senior High School, Plano, Texas

Sponsor: Julie Baker; Plano East Senior High School

Breast cancer occurs from contingency of malignant cells spreading through the bloodstream, affecting 2.3 million individuals globally, with HER2+ being an invasive subtype due to HER2 protein overexpression. However, current medications slow tumor growth rather than eliminate it, whereas therapies eliminate it but also diminish healthy cells; causing it to be not tailored to physical side effects. This research aimed to assess piperoyl-piperidine, a component in black pepper, effects on HER2+ breast cancer in *Drosophila melanogaster*, focusing on its potential to reduce cell proliferation, increase mobility, eating habits, and survivorship. It is hypothesized that higher doses of piperoyl-piperidine would yield a tumor growth inhibition (TGI) rate greater than 50%, along with reduced cancerous phenotypic traits. Three concentrations of piperoyl-piperidine were tested: T-1 at 0.1 μM , T-2 at 0.2 μM , and T-3 at 0.3 μM over a period of 10 days. T-3 demonstrated a TGI of 80.11%, T-2 showed 68.22%, and T-1 showed 44.84%, with higher concentrations associated with tumor reduction, greater mobility patterns, eating habits, and survivorship. Both t and p value analysis confirmed that each variable tested rejected the null hypothesis and deemed as significant statistical difference. Future research will test higher doses and explore its effects on various cancers, contributing to a diverse set of patient populations. By understanding the inhibitory effect of piperoyl-piperidine on HER2+ breast cancer, we can accumulate extensive knowledge involved with cancer onset and growth. From there, we are one step closer to a cure.



Virginia

GEMINI: A Breakthrough System for Robust Genetic Interaction Discovery, Revolutionizing Biological Insight For the Discovery of Novel Gene Regulatory Networks and Application of Gene Regulatory Networks to Industrial Level Genetic Engineering

Ridhi Gutta

Academies of Loudoun, Leesburg, VA

Sponsor: Dr. Daniel Crowe, Academies of Loudoun

Mentors: Dr. Johanna Cannon, Academies of Loudoun & Dr. Patrick White, Academies of Loudoun

In order to resolve crucial global issues, the widespread application of genetic engineering at an industrial level is key. However, the majority of synthetically engineered strains fail at the industrial level due to disruptions in gene regulation. This stems from a lack of understanding and usage of gene regulatory networks (GRNs), which control cellular processes and metabolism. Effective manipulation of GRNs can improve product yield and functionality significantly. However, current GRN inference tools are extremely slow, inaccurate, and incompatible with industrial scale processes, because of which there are no complete expression based GRNs for any organism. This research proposes a novel computational system, GEMINI, to enable fast GRN inference for integration into industrial scale pipelines. GEMINI consists of two main parts. First, we create a novel mutual information algorithm that replaces traditional sequential inference methods, ensuring compatibility with parallel processing. Second, we integrate a novel GNN architecture based on spectral convolution to efficiently learn global and local regulatory structures. On in silico benchmarks, GEMINI outperforms all industry leaders, achieving a nearly 300% increase in AUPRC compared to the industry leading method, GENIE3. GEMINI also reduced computing time by a factor of 9.5 and was able to perform on a classroom GPU. When applied on a real *E. coli* dataset, GEMINI not only recovered 98% of existing interactions, but discovered 468 novel candidate interactions, constructing the most complete expression based GRN of *E. coli* to date, providing a novel biological blueprint for genetic engineers to use at the industrial level.

Combating Alzheimer's Disease: Design and Synthesis of a Novel Drug Molecule for Targeted Metal Chelation Therapy

Avani Kaur

Mills E. Godwin High School, Henrico, VA

Mentor: Dr. Michael Norris, Department of Chemistry, University of Richmond

Purpose: Alzheimer's Disease (AD) is the sixth leading cause of death, and there is an urgent need for innovative treatments. Metal dyshomeostasis, a hallmark for AD, is characterized by the accumulation of certain toxic metal-ions in the brain. These metals catalyze the production of free radicals, resulting in metal-induced oxidative stress and exacerbating neurodegeneration. Metal chelators selectively bind to metal-ions to form stable complexes that can be safely excreted from the body, thereby alleviating oxidative stress in AD. Therefore, this study aims to synthesize a novel metal chelator as a potential therapeutic agent for targeting. Methods: A ligand was synthesized, and its structure was confirmed utilizing Nuclear Magnetic Resonance spectroscopy. UV-Visible spectroscopy was implemented to assess the metal-chelating ability. Finally, the logP test was performed to determine the molecule's ability to penetrate the Blood-Brain Barrier. It was hypothesized that the ligand would effectively chelate toxic metals, specifically targeting Fe(III), Zn(II), and Cu(II), thereby mitigating metal-induced oxidative stress as a potential treatment for AD. Results: The results revealed that the novel ligand exhibits metal-chelating properties and has therapeutic potential for combatting AD progression. A one-way ANOVA was conducted and



revealed that the data is statistically significant. The research hypothesis was supported. Conclusion: The efficacy of the novel molecule stems from its structural properties, chemical behavior, and drug-likeness. Chemically, Schiff bases form strong coordinate covalent bonds with specific metal centers, possess enhanced binding affinities, and electron delocalization, making them ideal candidates for targeted metal-chelation therapies aimed at mitigating AD.

Targeting RAGE: A Novel Therapeutic Strategy Against AGE-Mediated Prostate Cancer Progression

Bhoomika Kaur

Mills E. Godwin High School, Henrico, VA

Mentor: Dr. David P. Turner, Virginia Commonwealth University

Purpose: The accumulation of advanced glycation end products (AGEs) and their interaction with the receptor for AGEs (RAGE) have been implicated in the progression of prostate cancer (PCa), the second most diagnosed cancer in men worldwide. However, therapeutic strategies targeting RAGE remain underexplored, representing a critical gap in current cancer treatment approaches. This study aimed to investigate the role of the AGE-RAGE signaling pathway in PCa progression, focusing on how RAGE inhibition affects cell migration and how RAGE knockdown influences both migration and proliferation. Methods: RAGE inhibition was achieved using TTP-488 in DU145 cells, and a migration assay assessed cell migration in response to the following treatments: no treatment (NT), the negative control; AGEs, the positive control; TTP-488; and AGEs & TTP-488. RAGE knockdown was performed via shRNA transfection in LNCaP cells, confirmed by Western Blot analysis. A Trypan Blue Proliferation assay evaluated cell growth in LNCaP shRAGE and shControl cells, while a migration assay determined migration in those cells. It was hypothesized that RAGE inhibition and knockdown would reduce PCa cell migration, with knockdown specifically reducing proliferation. Results: ANOVA and post-hoc analyses revealed that disrupting AGE-RAGE signaling via inhibition and genetic knockdown effectively mitigates cell migration, with knockdown also significantly hindering cell proliferation. These findings support the research hypothesis. Conclusion: Targeting RAGE in PCa reveals a transformative therapeutic approach to control tumor progression and metastasis, set to redefine cancer treatment globally. Future studies should explore combining RAGE disruption with conventional treatments like chemotherapy.

From Theory to Observational Results: Baryon Acoustic Oscillations Detected at High Redshift Ranges

Kevin Zhang

Academies of Loudoun, Leesburg, VA

Mentor: Jiani Chen, University of Southern California

The current mission from several space science institutions occurring on a global scale is the search for baryon acoustic oscillation (BAO) peaks. In our work, we were able to successfully discover a BAO peak detected by the Dark Energy Spectroscopic Instrument (DESI) Early Data Release (EDR) at a higher redshift range than the current published work. In our study, we chose a selection of 60,431 quasars between redshifts ranges from $2 < z < 3$. We followed the methods used by current scientists which was to compute the correlation function, revealing a peak at roughly $110 h^{-1}$ Mpc at a significance value of $4 \cdot 10^{-73}$ compared to a correlation function associated with a pure CDM model. The detection of the BAO peak in the DESI EDR is significant as it shows the potential of DESI as a powerful tool to determine the BAO standard ruler across a wide range of redshifts, with the 2025 official DESI data release providing even more data to conduct in-depth studies on BAOs. Based on this result, future analyses can help refine the



position of the BAO peak at high redshifts and uncover new values for cosmological parameters within the early universe.

Virtual

OsteoNexus: Attention-Driven Neural Networks for Osteoporosis Detection

Saanvi Chakraborty

Mason Classical Academy, Naples, FL

Often doctors need multiple medical tests to confirm if a patient has osteoporosis or not and this takes a lot of time leading to the disease-causing severe damage. This research focuses on developing a deep learning model for detecting osteoporosis in knee X-rays by combining attention mechanisms, LSTM networks, and autoencoders. The goal is to improve the accuracy and efficiency of osteoporosis detection, utilizing both spatial and temporal dependencies within the image data. The procedure involves preprocessing knee X-ray images and training a neural network that incorporates an attention mechanism to highlight key features, an LSTM layer to capture temporal patterns, and an autoencoder for unsupervised feature extraction. The model is trained using labeled knee X-ray images, and its performance is evaluated on a separate test set. Results show the model's ability to classify knee X-rays into two categories: healthy and osteoporosis affected. The model achieved a test accuracy of 90%, and the confusion matrix analysis confirmed its classification effectiveness. These findings suggest that this model could be applied in clinical settings for automated osteoporosis detection, offering potential benefits for early diagnosis and reducing the impact of human error on bone damages. By automating the detection process, it reduced the time and effort required for manual analysis, enabling faster diagnosis and better patient outcomes. The system could be integrated into existing healthcare infrastructure, supporting radiologists to improve patient care.

How Do Sleep and Gender Impact Recognition of Emotions and Faces?

Lillian Costen

Roanoke Valley Governor's School, Roanoke, VA

Teacher: Melissa Fisher, Roanoke Valley Governor's School

The purpose of this quasi-experimental study was to determine the impact of sleep and gender on emotional and facial recognition. The hypotheses of this study were that inadequate sleep would have a negative impact on facial and emotional recognition and that women would outperform men on facial and emotional recognition tasks, regardless of sleep adequacy. There were 48 participants in this study, with twenty-six females and twenty-two males. The average participant was sixteen years old. All participants were from Roanoke Valley Governor's School and gave informed consent before participating in this study. First, participants completed a demographic questionnaire and questions from the Pittsburgh Sleep Quality Index (PSQI). Then, participants completed the Emotion Recognition Task (ERT) and the Glasgow Face Matching Task 2 (GFMT2). Results suggest females and males had similar sleep quality, with no significant difference between the mean PSQI scores ($p = 0.444$). Female GFMT2 scores were significantly different than male GFMT2 scores ($p = 0.013$), with females having a mean of 86.54 and males having a mean of 82.39. Additionally, female and male scores on the ERT were significantly different ($p = 0.014$), with females having a mean score of 64.58 and males having a mean score of 55.7. Sleep did not have a significant impact on facial or emotional recognition ($p = 0.261$ and 0.645 , respectively). Overall, sleep did not influence facial or emotional recognition, but gender did; females outperformed males on both recognition tasks.



Key Drivers of Patient Loyalty

Hailey Kim

Marriotts Ridge High School, Marriottsville, MD

Patient loyalty is a critical component of healthcare quality, influencing patient adherence, engagement, and continuity of care. While doctor reputation has been recognized as an essential factor in healthcare decision-making, its direct impact on patient loyalty remains unclear. This study examines the relationship between doctor reputation and patient loyalty, proposing that patient-centered care serves as a mediator in this relationship. A quantitative survey-based approach was employed, recruiting 250 U.S. patients through Amazon Mechanical Turk (MTurk). Participants completed validated 7-point Likert-type scales measuring doctor reputation, patient-centered care, and patient loyalty. Reliability analyses confirmed strong internal consistency for all constructs (Cronbach's $\alpha > .80$). Hypothesis testing using linear regression supported the positive relationship between doctor reputation and patient loyalty ($t = 15.96$, $p < .001$). Mediation analysis using the Hayes (2017) PROCESS macro confirmed the indirect effect of patient-centered care (indirect effect = .48, 95% CI [.34, .62]), supporting the mediating role of patient-centered care in strengthening the relationship between doctor reputation and patient loyalty. These findings suggest that while doctor reputation establishes an initial foundation for trust, patient-centered care is a key determinant of long-term patient commitment. The results emphasize the importance of integrating patient-centered practices to enhance loyalty beyond reputation alone. Future research should explore longitudinal effects and expand the study across diverse healthcare settings to improve generalizability.

Continual Learning-Based Approach to Enhancing Optical Character Recognition for Low-Resource Languages

Aiden Ko

Korea International School, Seongnam-si, Republic of Korea

The state-of-the-art optical character recognition (OCR) tools are often only effective on a narrow scope of languages and scripts, which limits their applicability for many users worldwide. This is largely due to a lack of data used in training the machine learning models for OCR tasks, giving such languages the title of “low-resource languages.” Even when additional data for such languages become available, traditional methods for refining such tools with new data are not efficient, further reducing the incentive for development in practical applications. A class of learning approaches called continual learning offers a remedy through its potential to incorporate new data into existing deep learning algorithms efficiently and accurately without significant time or resource requirements. We explore one continual learning approach, namely the replay method, as a means to improve an OCR engine's performance for Hangul, the Korean writing system. We experimentally evaluate the effectiveness and efficacy of continual learning by measuring the performance of a deep neural network when it is trained through the replay method. Our findings indicate that continual learning, implemented with certain sampling rates of the replay method, demonstrates promising results rates in advancing OCR for Hangul, thereby possessing potential to help resolve the low-resource problem.



Dynamic Spectrum Access (DSA) for Opportunistic Spectrum Sharing in Next-Generation 6G Networks with Heterogeneous Wireless Devices

Ankit Walishetti

Illinois Mathematics and Science Academy, Aurora, IL

Mentors: Dr. Randall Berry and Dr. Igor Kadota, Northwestern University

As highlighted in the National Spectrum Strategy, Dynamic Spectrum Access (DSA) is key for enabling 6G networks to meet the increasing demand for spectrum from various, heterogeneous emerging applications in densely populated environments. In this paper, we model heterogeneous wireless networks with multiple 6G base stations (BS) and a limited number of frequency bands available for transmission. Each BS is associated with a geographical location, a coverage area, and a bandwidth requirement. To avoid harmful signal interference, we impose that BSs with overlapping coverage areas must use different frequency bands. We address the problem of efficiently allocating contiguous frequency bands to BSs while avoiding interference. Specifically, we define insightful performance metrics that capture the feasibility of the frequency allocation task, the number of BSs that can be allocated within the limited frequency bands, and the amount of resources utilized by the network. Then, we develop five different DSA algorithms that prioritize BSs based on different features—one of these algorithms is known in the graph theory literature as Welsh-Powell graph coloring algorithm—and compare their performance using extensive Monte-Carlo simulations. Our results show that DSA algorithms that maximize the chances of obtaining a feasible frequency allocation -- which have been widely studied in literature -- tend to underperform in all other metrics. Interestingly, our novel Bandwidth-Coverage DSA algorithm achieves the lowest bandwidth consumption compared to popular allocation methods from prior studies. Such innovative DSA methodologies enable high-speed, reliable connectivity for intelligent transportation systems, virtual reality, and numerous high-bandwidth 6G applications.

Washington

A Novel Method of Water Purification: Optimizing Foam Fractionation for Effective Broad-Spectrum Removal of DBP and DBP Precursors in Chlorinated Drinking Water

Lakshmi Agrawal

Interlake High School and Stanford Online High School, Bellevue, WA

Mentor: Kirin Furst, George Mason University and Virginia Polytechnic Institute and State University

In the 20th century, water treatment plants began using disinfectants like chlorine to eliminate waterborne diseases such as cholera and typhoid. However, this process results in the formation of disinfection byproducts (DBPs), toxic compounds formed when disinfectants react with natural organic matter (NOM) in water. The precursors to DBPs are the organic and inorganic substances that participate in these reactions. Epidemiological studies have demonstrated a significant association between DBP exposure and an 80% increased risk of bladder cancer in males, along with detrimental reproductive outcomes in females. Despite EPA guidelines for DBP removal in water treatment plants, approximately 70% of halogenated byproducts in conventional drinking water remain unidentified, making them difficult to remove. Current treatment methods (e.g., granular activated carbon, nanofiltration, and reverse osmosis) for removing precursors and DBPs incur significant energy demands and operational expenses. Foam fractionation is a water purification technique that separates surfactant-containing foam from liquid solutions using bubbling columns to induce phase separation. Foam fractionation has never been used or optimized for DBP and DBP precursor removal in chlorinated water. Many DBPs and precursors



are amphiphilic; this surfactant-like property facilitates their effective removal through foam fractionation. A pilot-scale foam fractionator was developed; a statistical analysis of the findings reveal a direct relationship between key variables (foaming stability, air flow rate, foaming agent concentration and type) and the removal efficiency of the target analytes (precursors). Results demonstrate that foam fractionation is both a viable and sustainable alternative for removing DBP and DBP precursors from chlorinated freshwater.

In Silico Simulation of Aptamer-Tau Interactions for Alzheimer's Disease Therapy

Navneeth Badhri

Redmond High School, Redmond, WA

Mentor: Gaurav Sharma, Eigen Sciences

Alzheimer's disease (AD) is the leading cause of dementia, characterized by the pathological accumulation of amyloid-beta ($A\beta$) plaques and tau protein aggregates, which disrupt neuronal signaling and lead to cognitive decline. In recent years, aptamers—short, structured oligonucleotides with high affinity and specificity for target biomolecules—have emerged as promising therapeutic agents for neurodegenerative diseases. Recently, bi-specific DNA-based aptamers, which first pass the BBB via transferrin receptors and later inhibit tau oligomerization, have been developed. I hypothesize that tau proteins contain specific binding sites that enable aptamer interaction, thereby preventing fibril formation. This study focuses on the computational characterization of bi-specific aptamers that facilitate blood-brain barrier (BBB) penetration via transferrin receptors and subsequently inhibit tau oligomerization. The three-dimensional structures of aptamers were generated using the Vfold, incorporating both secondary and tertiary structures. Molecular docking simulations were conducted using HDOCK to analyze aptamer interactions with transferrin receptors and tau proteins. P2Rank further validated the docking results for binding site prediction and electrostatic surface potential (ESP) analysis to assess complementarity and molecular interactions. Lastly, molecular docking results were analyzed using virtual reality (VR) technology. Among the aptamers tested, BW1c exhibited a strong binding affinity to tau protein, suggesting its potential as a first-in-class aptamer-based therapeutic for AD. In addition to computational simulations, I have also designed a novel aptamer analysis pipeline (APTASCAN) that can be used to facilitate future aptamer research. These findings provide a computational framework for designing novel aptamer-based interventions for neurodegenerative disorders.

A Novel GenAI Approach To Generate *De Novo* Terpene Synthase Enzymes By Fine-Tuning ProtGPT2

Hamsini Ramanathan

Seattle Academy of Arts and Sciences (SAAS), Seattle, WA

Mentor: Roman Bushuiev, IOCB Prague

In the vast protein space of 1 billion functional proteins, about 750 million functional proteins remain unexplored today. *De novo* proteins in this vast space have numerous life-changing applications in personalized medicine, disease diagnosis, biocatalysis, and biotechnology. However, designing *de novo* proteins using traditional techniques like Directed Evolution is resource intensive and typically takes several months to years. Recent advances in GenAI technologies like protein language models (PLMs) offer a promising solution. We hypothesized that if we fine-tune a PLM like ProtGPT2 with a protein family like Terpene Synthase (TPS) enzymes, the fine-tuned model can generate *de novo* TPS protein sequences with valid structures. We fine-tuned a distilled tiny version of ProtGPT2 using a dataset of 79,000 TPS sequences mined from UniProt and used the fine-tuned model to generate an initial set of 28,000 new TPS sequences. From this set of 28,000 sequences, we finally filtered down to seven putative



de novo TPS enzymes with low perplexity scores, high TPS detection scores, valid 3D structures, and relatively low sequence identity to our training set. The CLEAN model also classified the seven sequences as TPS enzymes. The InterPro model found at least one TPS domain in each of the seven sequences providing additional validation. Six of the seven sequences were classified as druggable proteins by the SPIDER model. Our novel GenAI approach to protein design offers a scalable in-silico method for discovering valid *de novo* protein candidates in the vast protein search space, significantly accelerating protein design and drug discovery.

ForeCAT: Advancing Clear Air Turbulence Prediction for Aviation Safety with Atmospheric Physics Informed Neural Networks and Spatiotemporal Weather Data

Aditya Sengupta

The Overlake School, Redmond, WA

Unexpected turbulence, particularly Clear Air Turbulence (CAT), remains one of aviation's most serious challenges, causing passenger injuries, operational disruptions, and costing airlines \$500 million annually. CAT accounts for 70% of weather-related aviation incidents, with climate change expected to double its frequency in the coming decades. The recent Singapore Airlines turbulence event in May 2024, which resulted in fatalities and injuries, highlights the urgency for improved prediction. Detecting CAT is challenging due to its occurrence in clear air, making conventional algorithms operational in the aviation industry, like Graphical Turbulence Guidance (GTG), less effective due to their reliance on linear, thresholded metrics. ForeCAT offers a breakthrough approach by integrating Artificial Intelligence (AI) with atmospheric physics. Using partial differential equations (PDE) based turbulence diagnostics, ForeCAT's neural network captures complex turbulence interactions for accurate predictions. ForeCAT achieves 95.5% classification accuracy, three times higher than GTG. Additionally, ForeCAT accurately predicts Eddy Dissipation Rate (EDR), the industry-standard turbulence intensity metric. ForeCAT successfully predicted severe turbulence at the Singapore Airlines event location with 87% confidence, demonstrating its potential to mitigate such incidents. ForeCAT is integrated into LoCATe, an app for real-time CAT prediction, aiding pilots and air traffic controllers in proactive flight path adjustments. To further enhance model accuracy, CATalog, a low-cost turbulence measurement device, is developed to crowdsource and democratize access to turbulence data. By leveraging AI and physics-based diagnostics to significantly advance accurate CAT forecasting, ForeCAT provides a transformative solution for enhancing aviation safety and navigating the increasingly turbulent skies of the future.

Artificial Intelligence-Guided Catheter Design for Patient-Specific Coronary Vein Procedure

Zain Shariff

Curtis Senior High School, University Place, WA

Mentor: Nasir Shariff- Cardiac Electrophysiologist, CHI Franciscan Medical Group

CT scans are used in the medical field to identify a patient's anatomical features non-invasively. The coronary sinus ostium is a vital structure used in procedures for coronary venous system access but poses a challenge to physicians with its varied and small anatomy. Artificial Intelligence segmentation models and additional programs could utilize CT scans to create a 3D printable catheter sheath that can assist physicians in these procedures.

A dataset was compiled of 4789 CT scans from the LIDC-IDRI with annotated cardiac structures from the Superior Vena Cava to the Coronary Sinus Ostium. A YOLOv11 Extra Large Segmentation Model was trained from scratch on this dataset for 778 epochs. This model



achieved a mAP50-95 score of 0.67656 and F1 Score of 0.93. These statistics demonstrate the model's high accuracy.

A Python Application was curated by this study. It features the trained AI model identifying and segmenting the structures that the catheter will pass through. This data is analyzed for plausible points and a smoother algorithm was used to remove sharp vertices. The program outputs a .stl file that could be used to 3D print.

Statistics were collected and shown that the catheter had appropriate length and clearance from cardiac structures.

This study creates a cutting-edge technology that can be utilized to assist physicians in coronary sinus ostium related procedures. Further training of the model, a practicality assessment to determine catheter materials and confirm use case, as well as clinical trials are required before actual implementation in the field.

West Virginia

Heat Exchanger Design and Optimization

Maya Panta

Woodrow Wilson High School, Beckley, WV

Mentor: Dr. Yogendra Panta, WVU Tech

The Shell and Tube Heat Exchanger is widely used in high-pressure industrial applications such as petrochemical processing and offshore oil rigs. This study examines the thermal performance of an HT33 Shell and Tube Heat Exchanger Unit (Armfield, Inc.) with a 20,000 mm² heat transfer surface area, 144 mm heat transfer length, and 44.45 mm shell diameter housing seven smaller tubes (6.35 mm each) with six semicircular baffles. A countercurrent flow configuration was used, with cold water circulating through the shell while hot water flowed in the opposite direction at controlled velocities.

The primary objective is to analyze how varying hot fluid velocities impact heat exchanger effectiveness. Experimental testing and computational modeling using ANSYS Fluent's finite volume method (FVM) were conducted. Results showed that increasing hot fluid velocities improved heat transfer effectiveness by up to 7%. However, overall effectiveness remained low (0.22) due to potential pressure stabilization issues, fouling, insulation inefficiencies, and structural constraints. CFD simulations predicted an effectiveness of 0.28, revealing a 27% discrepancy between experimental and simulated results.

To enhance heat transfer, two geometric design modifications were proposed. The first incorporated 15 radially placed straight fins, increasing the heat transfer surface area by up to 250% and potentially improving effectiveness to 0.50. The second introduced U-shaped tubes embedded with similar fins, further expanding the surface area by 300%, potentially achieving even greater effectiveness. Ongoing ANSYS Fluent and MATLAB simulations aim to validate these designs for industrial applications, optimizing heat exchanger performance and thermal efficiency.



DNA Damage and Repair Mechanism in Duckweed (*Spirodela polyrhiza*) Under Ultraviolet (UV-B) Radiation Stress

Manvitha A. Sanjaya

George Washington High School, Charleston, West Virginia

Mentors: Dr. Shivasharanappa Patil, West Virginia State University and Dr. Shobhan Gaddameedhi, North Carolina State University

Teacher: Mr. Joseph Gibson, George Washington High School

In living organisms, DNA is a critical macromolecule; its stability and integrity are vital for the normal functioning of cellular processes, such as DNA replication repair. Sunlight is a significant source of ultraviolet (UV) radiation. Excessive exposure to UV-B radiation can cause damage to DNA structure by introducing DNA lesions such as cyclobutane-pyrimidine dimers (CPDs) and 6-4 photoproducts (6-4PPs). These negatively affect the physiological processes of living organisms.

In this study, duckweed (*Spirodela polyrhiza*) plantlets were exposed to different UV-B exposure times. After UV-B exposure, plantlets were recovered under normal growth conditions and sampled at 0 hours, 12 hours, and 24 hours for genomic DNA damage analysis. The quality and integrity of the genomic DNA were tested by gel electrophoresis. Genomic DNA was probed on a slot-blot experiment for antibodies against the CPDs/6-4PPs to detect damaged DNA and DNA repair capacity.

Our results suggest that duckweed plantlets at 0 hours of post-UV-B recovery had the strongest CPDs/6-4PPs signal intensity; thus, in these samples, the DNA repair mechanism did not have enough time to repair the damaged DNA. Weaker CPDs/6-4PPs signals were observed in the 12 and 24-hour recovery times post-UV-B treatment. In situ visualization by DAB staining revealed increased H_2O_2 in the 0-hour post-UV-B recovery plantlets. DNA damage, DNA repair mechanism, and accumulation of H_2O_2 in duckweed are UV-B dose-dependent. Our work suggests that duckweed is ideal for studying UV-B-mediated DNA damage as an alternative to mammalian systems to understand the effect of climate change on plant and human health.

Machine learning optimized in silico design of a de novo RAGE inhibitor: a small molecule approach to slowing the progression of inflammatory disease

Pavan Subramani

Morgantown High School, Morgantown, WV

Mentor: Soumya Prasad, Candor Care, PLLC

Inflammatory diseases affect billions of patients worldwide. Receptor for Advanced Glycation End products (RAGE) has been identified as a promising target for many inflammatory diseases, including cancer, diabetes, and neurodegenerative disease. I hypothesized that computational methods could effectively design oral small molecules with a strong affinity for RAGE and favorable pharmacokinetic properties.

Proteomics analysis showed that RAGE is not involved in major protein pathways and inhibition will have few downstream effects. The ZINC20 database was filtered from 883 million compounds to 405 million using standard drug-likeness properties. A deep neural network created a pharmacophore model by identifying interaction sites on the structure of RAGE using instance segmentation. I then screened the filtered database for fit to binding sites on RAGE using this pharmacophore model, ranking compounds based on the distance from pharmacophore features. This resulted in 208 molecules, which were optimized for docking affinity to RAGE through evolutionary fragment-based optimization. Binding affinities were validated through SwissDock.



Through an ensemble of ADMET tests the final compounds were predicted to be safe in humans. Drug-drug interactions for cardiac side effects with common chemotherapeutics were evaluated as RAGE increases resistance to chemotherapies. Two compounds were isolated, one intentionally blood-brain barrier (BBB) permeable, and both with affinities below -10 kcal/mol and favorable ADMET properties, confirming the hypothesis.

The first drug (PUV6060) will be applicable in treating inflammatory disease. The second drug (PUV4259), which is BBB permeable, will be used to treat neuroinflammatory disease. Future directions include validation in animal models and reaching patients.

Consequences of TRPV1 Knockout in Human U87 Glioblastoma Mediated by Capsaicin

Iqraa Zaman

George Washington High School, Charleston, WV

Mentor: Dr Subrayaman Chinreddy

Glioblastoma is a highly aggressive brain malignancy with a 5-year survival rate of 6.9%. The transient receptor potential vanilloid-1 (TRPV1) ion channel has been studied for its activation by capsaicin, a phytochemical with anti-cancer properties. TRPV1 knockout promotes tumor proliferation through p53 pathway inhibition, a crucial tumor suppressor. While TRPV1 has been implicated in tumor suppression, the effects of its knockout on capsaicin-dosed glioblastoma remain unexplored. This study simulated TRPV1 knockout to elucidate the consequences of capsaicin on apoptosis, metastasis, and p53 expression in TRPV1 knockout U87-MG glioblastoma. Using CRISPR-Cas9 technology, a TRPV1 knockout was simulated in human U87 glioblastoma. Knockout and control cells were treated with 100-225 micromolar capsaicin and ethanol. WST-8 cell viability assays, scratch-healing migration, and RNA sequencing revealed that TRPV1 knockout amplifies capsaicin's anti-tumor effects, effectively suppressing cancer. WST-8 cell viability assays, sampled at 24 h, 48 h, and 72 h, showed dose- and time-dependent apoptosis, with TRPV1 knockout cells exhibiting greater capsaicin-induced apoptosis. Scratch-healing migration assays at 24 h demonstrated that capsaicin-treated knockout cells exhibited no gap closure, while ethanol-treated knockout cells observed 100 micrometers of gap closure. RNA sequencing identified greater upregulation of p53 in knockout cells, suggesting increased apoptosis. IC50 values indicated that 164.4 micromolar capsaicin caused the most pronounced cancer suppressive effects on TRPV1 knockout cells. These findings imply that TRPV1 knockout enhances capsaicin's anti-tumor effects, making TRPV1 a promising target in anti-cancer treatments. Applications of this research can explore the feasibility of capsaicin-based drugs to target TRPV1 in brain cancer patients.

Wisconsin/Upper Peninsula Michigan

Development and Comparative Analysis of ApolloHealth: A Mobile Application to Search for Free and Low-Cost Healthcare Clinics

Ali Abidi

Onalaska High School, Onalaska, WI

Mentor: Syed Abidi

Free and low-cost healthcare clinics are crucial for providing equitable healthcare to approximately 27 million uninsured individuals in the U.S. and those who cannot afford medical bills. Uninsured patients usually delay seeking primary care, leading to worsened health outcomes and increased strain on emergency health services. To alleviate this, government and non-profit agencies offer lists of free and low-cost clinics and websites to search for them, but these



platforms often lack functionality and efficiency. Additionally, no centralized mobile application provides clinic information across all states. This project aimed to develop a free mobile application, ApolloHealth, to address these challenges. The hypothesis stated that ApolloHealth, with its nationwide free and low-cost clinic database, improved search efficiency, and enhanced usability, would outperform existing online search platforms. ApolloHealth was initially developed for the iOS platform, with clinic databases sourced from publicly available, authentic federal and state sources. This data was consolidated using Python, incorporating geolocation, website links, phone numbers, and service type tags for further organization. The app features a location-based, nationwide clinic search with service type selection, direct calling from within the app, Google Maps integration, and offline accessibility. A comparative analysis with three existing clinic search resources showed that ApolloHealth, with comprehensive search features and an average search time of 25 seconds, outperformed them in both functionality and search efficiency. The analysis proved that ApolloHealth demonstrates strong potential to improve access to affordable healthcare, reduce health inequity for uninsured populations across the U.S., and alleviate the burden on emergency health services.

An Analytic Pipeline to Compare the Functional Capacity and Transcriptional Profiles of Chimeric Antigen Receptor (CAR) T Cells and Bispecific T Cell Engagers (BiTEs).

Anand George

University School of Milwaukee, River Hills, WI

Mentor: Anthony E. Zamora, PhD, Assistant Professor, Medicine and Microbiology & Immunology, Medical College of Wisconsin

Chimeric Antigen Receptor (CAR) T Cells and Bispecific T Cell Engagers (BiTEs) have revolutionized the treatment of relapsed/refractory hematologic cancers. However, there are no head-to-head comparisons testing differences in their ability to induce T cell activation - a surrogate for their efficacy and toxicity. We hypothesized that differences in downstream signaling by anti-CD19 CAR-T cells and anti-CD3/CD19 BiTEs will lead to differential T cell functional capacity and transcriptional profiles. Spectral flow cytometry identified the optimal activation bead, and the Beacon Optofluidic system was used to analyze differences in phenotype, functional capacity, and transcriptional profiles between CAR T cells and T cells co-cultured with BiTEs. Signal seeking and validation experiments were performed to develop an analytic pipeline. Functional analysis demonstrated differential expression of cytokines (IFN- γ , TNF- α , Granzyme B, Perforin) in CAR T cells compared to T cells with BiTEs. CAR T cells showed greater polyfunctionality in cytokine secretion, more durable target engagement, increased likelihood of exhaustion, and higher CD8+ to CD4+ T cell ratios than T cells with BiTEs. Single cell RNA sequencing demonstrated a transcriptional basis for the differential cytokine expression between CAR T cells and T cells with BiTEs, which was confirmed by concordant protein expression at single cell resolution. The distinct mechanistic differences between CAR T cells and BiTEs indicate the need to balance toxicity with therapeutic efficacy in treatment selection. We demonstrate the feasibility of developing an analytic pipeline to analyze functional, transcriptional, and proteomic data at single cell resolution to help personalize cellular therapies.

A Novel Approach to Increase South Asian Legume Resilience and Productivity Under Waterlogging Stress Utilizing Rhizobium Inoculation

Riya Kalluvila

Hartford Union High School, Hartford, WI

Mentor: Dr. Ramakrishnan M. Nair, World Vegetable Center South & Central Asia Labs

Mungbean (*Vigna radiata*) and urdbean (*Vigna mungo*) are two staple protein-rich legumes grown predominantly in Asia. India is the major producer (3.17 million t) of mungbean from an area of



5.5 million hectares (ha). In parallel, urdbean (black gram) is a vital legume in India, where its production reaches 2.78 million tons from an area of 4.63 million ha. Mungbean and urdbean have the ability to fix atmospheric nitrogen through symbiosis with *rhizobial* bacteria (symbiotic microorganisms that form nodules on the roots of legumes). This nitrogen fixation process is essential for soil fertility and reducing the need for synthetic nitrogen fertilizers. Oxygen deprivation (root damage) caused by *waterlogging* is a major environmental problem for mungbean and urdbean growth. Waterlogging is an adverse abiotic stress and is becoming more frequent in semi-arid tropics, specifically, Hyderabad, India where the 22.13% rise in unseasonal rainfall is linked to climate change and damage to legume plants. The interplay between waterlogging stress and rhizobium inoculation has critical implications for crop resilience and productivity. This leguminous research study coherently investigates the effects of *rhizobium* in legume plant growth traits under various stage conditions, including the flowering stage and pre-flowering stage, and assesses the impact of *rhizobium* inoculation under control and waterlogging treatments. As primary hypothesis, rhizobium inoculation will enhance the resilience and productivity of legumes under waterlogging stress. Waterlogging treatment had a significant effect on both mungbean and urdbean genotypes. Root nodulation and total biomass were significantly increased under *rhizobium* inoculation.

Eco-Friendly Membrane Technology: Unlocking Antibacterial Potential of Biowaste Materials Against Foodborne Pathogens

Hannah Lee

Middleton High School, Middleton, WI

Mentor: Peter Lee, Kerry Inc.

Numerous studies have investigated the use of natural compounds for antibacterial applications. This study evaluated biowaste materials such as morro seed, moringa seed, strawberry seed, and citrus peel albedo for their antibacterial potential. The materials were subjected to hot water or acidic treatments, followed by extraction using membrane technology, and then tested against four major foodborne pathogens: *Escherichia coli* O157, *Listeria monocytogenes*, *Salmonella typhimurium*, and *Staphylococcus aureus*. Citrus peel albedo extract demonstrated strong antibacterial activity, effective at concentrations as low as 0.032 mg/ml across all bacterial strains. Moringa seed extract showed selective activity against Gram-positive bacteria with minimum inhibitory concentration (MIC) at 2,500 mg/ml and minimum bactericidal concentration (MBC) at 5,000 mg/ml. However, extracts from morro and strawberry seeds showed no antibacterial activity even at concentrations as high as 200,000 mg/ml. This research underscores the promise of biowaste materials as viable antibacterial agents, contributing to food safety and public health, while also promoting environmental sustainability through eco-friendly membrane technology in place of conventional solvent extraction methods.

Mitochondrial Ribosomal Protein-47 (MRPL47) identified as a diagnostic biomarker of ovarian cancer

Meenakshi Pradeep

New Berlin Eisenhower, New Berlin, WI

MRPL47 (Mitochondrial Ribosomal Protein Large Subunit 47) gene encodes a protein that is part of the large subunit of the mitochondrial ribosome. MRPL47 is located in the 3q26 locus of chromosome-3, a chromosomal position frequently amplified in ovarian cancer. MRPL47 is often highly amplified, or exhibits copy number gain as part 3q26 amplicon in ovarian cancer, which in turn resulted into an increase in the expression of MRPL47 mRNA and MRPL47 protein in ovarian cancer patients. Importantly, high expression of MRPL47 is correlates with poor level of survival of ovarian cancer patients. Gene set enrichment analysis and target specific knockdown assays



reveal that MYC transcription factor regulates MRPL47 expression. Our analysis further identified MRPL47 is blood samples, with significantly higher expression levels in plasma collected from ovarian cancer patients compared to those of healthy volunteers. Taken together, we demonstrate that MRPL47 can be used as a diagnostic biomarker for ovarian cancer and other cancers encompass 3q26 chromosomal amplification.

Wyoming and Colorado

Paper for the Planet: Kickstarting Microbial Succession Following California Wildfires

Naomi Kruse

Homeschool, Black Forest CO

Mentor: Tami Kruse

With unnatural wildfires disrupting ecosystems worldwide, they are leaving behind toxic ash, depleted microbial communities, and barren landscapes. In urban environments, the microbial elements necessary for natural secondary succession are often absent, preventing recovery. This study looks at the development and use of a cellulose-based, seed and/or fungi-infused paper, biodegradable paper to kickstart microbial and plant succession in post-fire urban and hard-burn settings.

Paper for Planet integrates three key remediation strategies found in nature: (1) *Neutralizing toxic ash—Pleurotus ostreatus* to break down pollutants and stabilize soil pH (2) *Restoring microbial communities*—introducing arbuscular and ectomycorrhizal fungi to reestablish soil microbiomes, and (3) *Enhancing plant establishment and carbon sequestration*—fire-adapted wildflowers and all trees grow more successfully in mycorrhizal environments, and support long-term carbon storage.

The methodology involves the development of cellulose-based paper testing its effectiveness in post-fire environments. Experimental conditions include variations in ash exposure (ash-contaminated soil and groundwater) and microbial inoculation (*Pleurotus ostreatus*, arbuscular mycorrhizal fungi, and ectomycorrhizal fungi). I analyzed changes in pH, seed germination success, and mycelium growth over 21 days.

I developed two programs to quantify mycelium and seed germination. Mycelia Measure utilizes Otsu's method and grayscale thresholding to analyze heart-shaped samples. Codeledon Count utilizes leaf color pixel detection to count leaves.

Paper for the Planet successfully grows *Pleurotus* mycelium at a rate that correlates to neutralized soil pH. It is also a successful medium used to introduce arbuscular fungi and ectomycorrhizal fungi, along with their symbionts, to charred soils, demonstrating its potential to kickstart post-wildfire recovery.

A Novel Method to Analyze Thermonuclear Explosions in Four Binary Star Systems Using NASA's High Time Resolution TESS Data

Padmalakshmi Ramesh

Laramie High School, Laramie, WY

Mentor: Kishalay De, Columbia University

Novae eruptions occur in interacting binary star systems when a white dwarf is accreting mass from its companion. When the shell of material reaches the flash point, a runaway thermonuclear



explosion occurs. This results in a sudden and substantial eruption that produces heavier elements and lithium in the universe. Analyzing the light curves of novae can help to understand unanswered questions about binary system, such as the reason why certain systems experience novae, mergers, or ejections. This study utilized time and flux data from the Transiting Exoplanet Survey Satellite for four novae, V2891 Cyg, PGIR22akgylf, V1711 Sco, and V567 Nor. These data were constructed into light curves to look at the general shape of the novae eruptions. The light curves were detrended to perform a Lomb-Scargle periodogram analysis to detect periodicities and other patterns. The period calculated from the max frequency was used to phase fold the light curve. A strong periodicity was detected in the nova PGIR22akgylf. Further analysis, such as a power law, can help determine if the other two novae also exhibit variations. These results are the first steps to answer the mysteries that surround novae and binary stars.

Hertz to Volts: Optimal Utilization of Sound Energy to Produce Electricity

Aanshi Shah

Legacy High School, Broomfield, CO

Sponsor: Parth Shah, SurgOne P.C.

Sound, which is unlimited, free, and readily available, has yet to be effectively explored as an alternate energy source. I designed an innovative method that utilizes sound energy to produce electricity using the principles of resonance and electromagnetic induction. I was met with challenges including suboptimal use of sound energy and not being able to produce a reasonable amount of current. To address these, I analyzed the variables affecting electricity production in a modified model incorporating the principles of electromagnetic induction and piezoelectricity. Models using magnetic repulsion along with electromagnetic induction were also tested. I hypothesized that optimization of voltage production using sound is possible through resonance, electromagnetic induction, and piezoelectricity or magnetic repulsion. I used a 440 Hz tuning fork for optimal resonance and 100 coils of insulated copper wire. I used a series of model units each consisting of a coil, piezo, and moving magnets. The data for the variables—the size of the ball, the size of the magnet, and the number of magnets—was analyzed using linear regression. All the variables had a significant impact on voltage production through electromagnetic induction. The voltage produced using piezoelectricity was independent of these variables. The model using magnetic repulsion with electromagnetic induction failed to produce an electric output. In conclusion, optimization of electricity produced is possible through the model using a combination of electromagnetic induction and piezoelectricity, especially when multiple such units vibrate together through the resonance. This could make sound an effective alternative to fossil fuels.

Combating Root-Knot (*Meloidogyne* spp.) and *Fusarium oxysporum* with Stabilized Allicin (*Allium sativum*) and siRNA Constructs

Om Vegesna

Fairview High School, Boulder, CO

Mentor: Jonathan Henn, University of Colorado Boulder

Meloidogyne spp., or the root-knot nematode, is the most destructive nematode disease worldwide and persists in threatening the sustainability of the vegetable industry in numerous regions. Currently, no environmentally green pesticide is registered to cure this disease and preserve plant health. Fusarium Wilt (*Fusarium oxysporum*) is a fungal vascular root disease with no registered cure, causing a 95% yield reduction in Cavendish bananas. In this experiment, allicin (*Allium sativum*) was used to treat root-knot-infected soil, with Velum (Fluopyram) as the standard control. Allicin has a fast degradation rate, chitosan encapsulation was performed to enhance efficacy. Oligonucleotides were designed to silence the virulence factor Secreted in Xylem 1 (SIX1) in Fusarium Wilt. Root gall index through visual measurements showed a 54.55%



decrease, confirmed with plant vigor physical measurement where the plant height increased by 15%. Soil porosity was used to measure the water retention of soil. The macropore content was higher in treated soil by 15%, respectively. Among the different concentrations (100 μ M, 500 μ M, 2 mM, 5 mM) of allicin, 2 mM was found to be optimal. Oligonucleotide sequence 2 demonstrated a TM of 56.2°C and 55.6% GC content. The siRNA conserved linear secondary structure, providing strong functionality. Based on the findings, allicin can be an effective and sustainable solution for root-knot management, supporting the global agriculture industry, while oligonucleotides have the potential for effective knockout of Fusarium Wilt virulence, with implications on the economy and food security.

**Optimization of Electroporation Based CRISPR Protocol in Immortalized B-cells:
For future studies on the role of a PTPN2 SNP in dysregulation of immune function**

Amy Xia

Cherry Creek High School, Greenwood Village, CO

Mentor Dr. Soojin Kim, Barbara Davis Center for Childhood Diabetes - CU Anschutz

In this study, I optimized a cost-efficient protocol for editing immortalized human B-cells using CRISPR delivery via nucleofection, GFP, and flow cytometry. In vitro human cell disease models are essential for studying and developing treatments for genetic diseases. The point mutation rs1893217 in the PTPN2 gene has been associated with multiple genetic autoimmune diseases such as type 1 diabetes through SNP linkage studies. It is unknown how the mutation alters immune response, as it is located within an intron. There is no existing model for this mutation in mice or human cell culture. To study this mutation, I optimized the CRISPR/Cas9 gene editing system for Burkitt lymphoma B-cell lines. B-cells are essential for understanding disease pathogenesis but are difficult to transfect due to their small size. The aim of this study was to use a cost-efficient nucleofection CRISPR delivery system and the GFP reporter gene to determine: optimal nucleofection program, whether to use DNA or RNA, and which B-cell line — BJAB, Daudi, Ramos, or Raji — showed the greatest potential to be genetically modified. Using the Lonza nucleofection program DS-104 and sgRNA, I achieved GFP expression of 83.15% in the BJAB cell line. These findings will be used to introduce the rs1893217 point mutation into B-cells to understand its role in B-cell regulation, specifically B-cell signaling. This model will help us understand how the SNP contributes to the dysregulation of the immune system and development of autoimmunity.

