

63rd Annual

CONNECTICUT HIGH SCHOOL SCIENCE and HUMANITIES SYMPOSIUM

at UConn Health,
Farmington, Connecticut

February 28, 2026



UCONN
HEALTH

OBJECTIVES

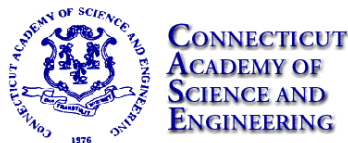
- To promote research and experimentation in science, technology, engineering, and mathematics (STEM) at the high school level.
- To recognize the significance of research in human affairs and the importance of humane and ethical principles in the application of research results.
- To search out talented youth and their teachers, recognize their accomplishments at symposia, and encourage their continued interest and participation in the sciences, technology, mathematics, and engineering.
- To expand the horizons of research-oriented students by exposing them to opportunities in the academic, industrial, and governmental communities.
- To increase the research and development capabilities of the future U.S. workforce.

Formerly known as the Connecticut Junior Science and Humanities Symposium (CT JSHS), this year's CT HSSH is made possible with support from

CT Area Health Education Center (AHEC)/UConn Health



Connecticut Academy of Science and Engineering



CT Department of Public Health (Public Health Infrastructure Grant)



Connecticut Science Supervisors Association



Connecticut Science Teachers Association



and

Cato T. Laurencin Institute for Regenerative Engineering (UConn Health)

Program Summary

	Saturday, February 21	Judging of Oral and Competitive Poster Presenters		
	Online February 23–27	Pre-week Events		
	Asynchronous timing	View and comment on STEM Poster Exhibition (alumni-mentored); view Competitive Posters and recordings of Oral Presentations.		
	Saturday, February 28	Symposium		
	7:45 – 8:40 AM	Registration		
	8:50 – 9:35 AM	Welcome & Keynote Address—everyone attends.		
Block #1	9:45 – 10:30 AM	1 st Oral Session Group A	Humanities Activity (students) Virtual Anatomy Lab Tour (chaperones) Group B	1 st Competitive Poster Session Group C
Block #2	10:40 – 11:25 AM	2 nd Oral Session Group B	Humanities Activity (students) Virtual Anatomy Lab Tour (chaperones) Group C	2 nd Competitive Poster Session Group A
Block #3	11:35 AM – 12:20 PM	3 rd Oral Session Group C	Humanities Activity (students) Virtual Anatomy Lab Tour (chaperones) Group A	3 rd Competitive Poster Session Group B
	12:30 – 1:00 PM	Awards Ceremony & Closing Remarks—everyone attends. <i>Winners will stay after 1:00 to learn details.</i>		
	1:00 – 1:15 PM	Grab a boxed lunch and depart.		

CONNECTICUT HIGH SCHOOL SCIENCE and HUMANITIES SYMPOSIUM at UConn Health

SATURDAY, FEBRUARY 28, 2026

REGISTRATION

7:45 – 8:40 a.m. Academic Lobby
Water and coffee outside Keller Auditorium

OPENING

8:50 – 9:35 a.m. Keller Auditorium

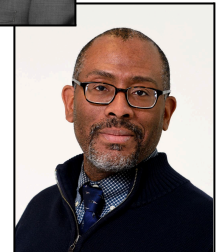
*Recorded
Welcome*



Andrew Agwunobi, MD, MBA
Chief Executive Officer, Executive Vice
President for Health Affairs, UConn Health
Recorded welcome: <https://tinyurl.com/3zaar2z6>



Anton Alerte, MD
Professor of Pediatrics and Associate Dean for
Primary Care, UConn School of Medicine



Briefing

Brittany Knight, PhD
Site Director, CT HSSHS
Director of Operations, United States
Association for the Study of Pain



Keynote Address **Angela Bermúdez-Millán, PhD, MPH**
Associate Professor of Public Health Sciences,
UConn School of Medicine
“The Effects of Food Insecurity on Health”



BREAK/TRANSITION

9:35 - 9:45 a.m. Refreshments

2026 HUMANITIES ACTIVITY: *Artificial Intelligence and Public Health*
Developed by Heather Biancheri, MS, Brookfield High School

UCONN HEALTH VIRTUAL ANATOMY LAB TOUR by John Harrison, PhD

BLOCK #1

9:45 – 10:30 a.m.

<i>Activity/ Location</i>	Group A: 1st Oral Session (Names are below.) Keller Auditorium	Group B: Humanities Activity (students) Massey Auditorium Virtual Anatomy Lab Tour (chaperones)	Group C: 1st Competitive Poster Session (Names are below.) Low Learning Center
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First Oral Session Presenters

Armaan Shrivastav

Amity Regional High School

Mentor: Dr. Chong Qiu

Developing a Fast-Response Aerosol Optical Depth Monitor for Continuous Information on Ambient Particulate Matter

Aryan Shrivastav

Amity Regional High School

Mentors: Dr. Jasna Jankovic and Antigoni Konstantinou

Developing a Bio-Hybrid Luminescent Solar Concentrator Using Carbon Quantum Dots, Natural Fluorophores, and Kaolin Powder for Enhanced Solar Energy Harvesting

Emily Barnhart

Bridgeport Regional Aquaculture Science and Technology Education Center

Mentor: Kirk Shadle

Utilizing Organic Byproducts within the Internal Arrangement of Concrete to Enhance the Dimensional Stability and Durability of Porous Concrete

Leonard Yeh

Amity Regional High School

Mentor: Gregory Burzynski, PhD

Developing a Quantitative Method to Minimize Personal Bias within Taxonomic and Phylogenetic Interpretations of Precambrian Disc Fossils

Vishnu Mukku

Avon High School

Mentor: Pranav Narnur

Integrating Copy Number Alterations and Transcriptomics with Machine Learning Improves Survival Prediction in HPV-Negative Head and Neck Cancer

First Competitive Poster Session Presenters

Bruno Reinhoefer Ribeiro

King School

Mentor: Dr. Simon Vecchioni

A Sustainable Treatment for Heavy Metal Pollution: Adsorption and Desorption of Ni(II) Ions in Water Using DNA-Wrapped Carbon Nanotubes

Christopher Alvarado

Joel Barlow High School

Mentor: Paul Testa

Assessing the Effectiveness and Performance of Adaptive Authentication in Isolation against Volumetric DDoS Attacks

Karthik Prem

South Windsor High School

Mentor: Vanessa Scanlon, PhD

Investigating the Role of Epigenetic Regulation on Primary Human Megakaryopoiesis

Leon Wang

King School

Mentors: Braxton Schuldt and Joel Blanchard, PhD

Repurposing Idiopathic Pulmonary Fibrosis Drugs to Treat Vascular Alzheimer's Dementia: A Safe, Effective, and Accessible Approach to Alzheimer's Treatment

Lilah Mehta

King School

Mentor: Dilpreet Kour, PhD

CX3CR1⁺ Cell Type-Specific ERK Hyperactivation Promotes Inflammatory Remodeling

BREAK/TRANSITION

10:30 – 10:40 a.m. Refreshments

BLOCK #2

10:40 – 11:25 a.m.

<i>Activity/ Location</i>	Group B: 2nd Oral Session (Names are below.) Keller Auditorium	Group C: Humanities Activity (students) Massey Auditorium Virtual Anatomy Lab Tour (chaperones)	Group A: 2nd Competitive Poster Session (Names are below.) Low Learning Center
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Second Oral Session Presenters**Mariam Welbeck** (group project with Farah Shahab)

Connecticut IB Academy

Mentor: Vanessa Scanlon, PhD

*Investigating the Functional Role of Heterodimeric and Homodimeric Erythropoietin Receptor in Megakaryocytic-Erythroid Fate***Ravindu Karunaratne**

Hamden Hall Country Day School

Mentor: Dr. Frank Gasparro

*Utilizing Exfoliated Graphite for Oil Extraction from Spills via Autonomous Robotic Devices***Sabrina Liu**

Choate Rosemary Hall

Mentor: Shiyao Gu

*NeuroMirror: A Hebbian-Theory–Based EEG-Driven Mirror Therapy System for Post-Stroke Upper-Limb Rehabilitation***Sahithi Aliminate**

Engineering and Science University Magnet School

Mentor: Kate Pippenger

*A Comprehensive Method to Combat Antibiotic Resistance in Soil Microbes: Integration of CRISPR-Cas9 Gene Editing and Nanoparticles for Enhanced Biodegradation of Pollutants***Tyler Malkin**

Greenwich High School

Mentor: Andrew Bramante

Development of a Novel Nanoparticle Drug-Delivery System Using OLAH Targeting to Deliver Surfactant Protein and Prevent Neonatal Respiratory Distress Syndrome

Second Competitive Poster Session Presenters

Campbell Saul Cohen

Bridgeport Regional Aquaculture Science and Technology Education Center

Mentor: Kirk Shadle

Development of a Crustacean β -chitin Biopolymer with Improved Functional Stability and Enhanced Decomposition

Claire Chan

Darien High School

Mentor: Mara Jaffe

Functionalizing DNA Nanotechnology: Optimizing the Impact of Buffer Conditions on Chemical Ligation

Mary Chickering

Greenwich Country Day School

Mentor: Dr. Nathan Haag

Convolutional Neural Network Classification of DaTSCAN Images for Parkinson's Disease with Interpretability Analysis

Nicholas Lu

Amity Regional High School

Mentor: Corey O'Hern, PhD

Simulating Droplet Breakup in Obstacle Arrays Using the Deformable Particle Model

Palaniappan Manikandan

CREC Academy of Aerospace and Engineering

Mentor: Lili Aramli, PhD

Optimizing the Efficiency of Solar Panels Using Enhanced Cooling Techniques

Rithvik Suren

CREC Academy of Aerospace and Engineering

Mentor: Thomas Brown

Next-Generation Interplanetary Rovers: Physical Implementation & Validation of Neuromorphic Artificial Intelligence Systems for Autonomous & Adaptive Terrain Exploration

Sarina Tian

Amity Regional High School

Mentor: Dr. Shuta Ishibe

Investigating the Effect of Podocyte-Specific Lrp1 Expression on Kidney Function and Podocyte Integrity

BREAK/TRANSITION

11:25 – 11:35 a.m. Refreshments

BLOCK #3

11:35 a.m. – 12:20 p.m.

<i>Activity/ Location</i>	Group C: 3rd Oral Session (Names are below.) Keller Auditorium	Group A: Humanities Activity (students) Massey Auditorium Virtual Anatomy Lab Tour (chaperones)	Group B: 3rd Competitive Poster Session (Names are below.) Low Learning Center
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Third Oral Session Presenters**Carolyn Hopstaken**

Joel Barlow High School

Mentor: Paul Testa

*Photocatalytic Degradation of Polypropylene via Iron-Modified Titanium Dioxide***Dillon Maltese**

King School

Mentor: Sarah Cha, MBA/MS

*A Voice-Controlled Robotic Arm for Assisting Complex Surgical Tasks***Lucia Vivanco**

King School

Mentor: Dr. Loretta Roberson

*Experimentation and Application of Nutrient Additives to Enhance Resilience of Coral Reefs against Climate Change***Marilyn Sommerville**

King School

Mentor: Dr. Ronald J. Emond

*Assessing the Effects of Equine Grazing Muzzles on Upper Incisor Length and Dental Qualities in Ponies***Nolan Francis**

Staples High School

Mentor: Amy Parent

*Vitamin D3 Supplementation Ameliorates Muscle Degeneration through Calcium Regulation in a Caenorhabditis elegans Model of Duchenne Muscular Dystrophy (DMD)***Rhea Doshi**

Kingswood Oxford School

Mentor: Ashkan Novin, PhD

AI-Powered Gait Analysis for Early Detection of Alzheimer's Disease and Mild Cognitive Impairment

Third Competitive Poster Session Presenters

Debbie Calixto Mota

Norwich Technical High School

Mentor: Kaitlin McKale

Blue Oyster Cult(ure): Using Pleurotus for Mycoremediation of Water Contaminants

Eva Figlar

Ridgefield High School

Mentor: Dr. Daniel Baluha

The Effect of Polyphenols and Ascorbic Acid on Iron Absorption in Zophobas morio

Hannah Deruz

Greenwich High School

Mentor: Andrew Bramante

Microneedle-Contact Lens Co-delivery of Azobenzene-Liposome Photoswitches and PEDF Neurotrophic Growth Factors to Repair the Effects of Macular Degeneration

Lula Wang

Greenwich High School

Mentor: Andrew Bramante

Design of a Novel, Dual-Functioning, T-Cell-Engaging, and Cytarabine-Based Nanotherapeutic for Acute Myeloid Leukemia Treatment

Nishant Jain

Greenwich High School

Mentor: Andrew Bramante

A Novel Dual-Targeting Therapeutic Patch for Non-addictive, Non-opioid Pain Suppression via Selective Transient Receptor Potential (TRP) Modulation

Victoria Makarov

Laurel Springs School (online)

Mentor: Vera Ulanovskaya

Optimizing Bus Fleet Allocation in Mid-sized Cities Using Mixed-Integer Nonlinear Programming: A Case Study in Stamford, CT

BREAK/TRANSITION

12:20 - 12:30 p.m. Refreshments

AWARDS CEREMONY AND CLOSING REMARKS

12:30 – 1:00 p.m.

Keller Auditorium

Evaluation

Submit completed form and receive a raffle ticket

Acknowledgments

Brittany Knight, PhD
Site Director, CT HSSH

Awards

- Poster Presenters
- Backyard Scientist Award
- STEM Poster Exhibition:
People's Choice Award
- Oral Presenters
- UConn Academic Excellence Scholarship

Barnes & Noble Gift Cards and Merchandise

- Exhibit Quest Participants
- People's Choice Award Voters
- STEM Poster Exhibitors
- Evaluation Raffle

Winners will stay after 1:00 to learn details.

ALL: PICK UP A BOXED LUNCH AND WATER "TO GO" AS YOU DEPART.

CHAPERONES: PLEASE SIGN OUT YOUR STUDENT(S) IN THE REGISTRATION AREA.

STEM Poster Exhibitors

Titiladeoluwa Adeniran, Engineering and Science University Magnet School

Investigating the Impact of Akkermansia muciniphila on Neuropathology in Parkinson's Disease Mice

William Aishman, Greenwich Country Day School

What Is the Effect of a 10-Second Body-Anchor Micro-Pause on Memory?

Olivia Ajayi, King School

Real-Time Instance Segmentation for Curb and Path Detection in Assistive Wearables for Blind and Low-Vision Assistance

Melany Almachi and Chloe Hutchins, The Sound School

Effects of Artificial Reefs on Sediment Profiles in Coastal Shorelines

Akil Arvind, Staples High School

Aligning ESG Emphasis with Human-Capital Disclosure: A Fifty-Company Content Analysis

Anit Arvind, Staples High School

Optimizing Fin Design for a Mars-Launched Rocket Using Modified OpenRocket Simulations

Ananyasri Baranidharan, Darien High School

Evaluating Fluorine-to-Hydrogen Substitution in PFOS to Predict Safer Variants Using Molecular Orbital Calculations

Gabriella Belizaire and Violet Sibley, The Sound School

Potential Impact of Plastic Leachate on Marine Phytoplankton Nitrate Uptake

Austin Bell, Bridgeport Regional Aquaculture Science and Technology Education Center

Solid-State Synthesis Using Metal-Supported Biochar to Minimize Polycyclic Aromatic Hydrocarbon Impurities

Vanessa Bell, CREC Academy of Aerospace and Engineering

Analysis of CYP2D6 Genetic Variation Using TaqMan qPCR to Predict Drug Metabolizer Phenotype

Arnav Bhatia, Greenwich High School

CD44-Targeted Nanoparticle Co-delivery of Simvastatin and Colchicine for Localized Treatment of Atherosclerotic Plaque Inflammation in Cardiovascular Disease

Joseph Christopher, Manchester High School

Is Knowledge Power? The Effect of Anatomical Learning on Athletic Performance

Sophie Ciambriello, Amity Regional High School

Assessing the Inclusion of Cultural Concepts in Professional Development Resources for African Women Physicians

Oliver Davis, Greenwich Country Day School

Simulating Satellite Orbits to Predict Decay and Lifespan

Shaelan Gara Grady, Manchester High School

The Impact of Presentation Styles on Engagement in Math Classes

Flora Guo, The Ethel Walker School

Mobility, Messaging, and Disease Risk under Compound Disasters: Evidence from Hurricane Laura

Jay Hari, Staples High School

Discovering Novel Targets for the FMN Riboswitch to Test the Utility of Computational RNA-Folding Methods to Address Multidrug Antibiotic Resistance

Warda Iqbal, Manchester High School

Investigation of Reptile UV Bulb on Vitamin D2 Synthesis in Pulverized Mushrooms: An Analysis over Specific Durations Using Thin Layer Chromatography (TLC)

Mia Jakubowsky, King School

Predicting Detectability of Transiting Exoplanets: A Python-Based Signal-to-Noise Ratio Model

Madison Kennedy, King School

Illuminating the Role of Lipid Metabolism Pathways in T-cell Exhaustion

Jacob Klee, Amity Regional High School

Determining the Effects of Saccharomyces cerevisiae in Remediating Diesel Hydrocarbons from Diesel-Contaminated Soil

Danlu Li, East Lyme High School

Multimodal Deep Learning for BI-RADS Prediction Using Breast Ultrasound and Patient Clinical Data

Jackson Lieberman, Greenwich Country Day School

Computational Engineering of a Thermostable Enzyme for the Degradation of PET through Manipulation of Disulfide Bonds

Adam Liu, Amity Regional High School

Investigating the Relationship Between a Novel Embodied Cognition Assessment to Predict Athletic Performance and Conventional Executive Function Testing and Individual Sports Achievement

Bryce Miller, Thomaston High School

Mood Variability across High and Low Physical-Engagement Gaming Conditions

Hana Mirza, Amity Regional High School

Developing a Cost-Effective Wearable Device for Monitoring and Real-Time Prevention of Apneic Events to Improve Sleep Safety in Individuals with Obstructive Sleep Apnea

Malala Naeem, Manchester High School

Effects of Microplastics on Plant Growth

Mahnoor Nomani, King School

Alarmin Release by Renal Cell Carcinoma Cells Undergoing Hypoxia-Induced Cell Death

Aiden Reyes, Bridgeport Regional Aquaculture Science and Technology Education Center

Development of a Dipole PVDF Film Pyroelectric Generator Utilizing Process Waste Heat

Brianna Ronalter, Thomaston High School

Evaluation of the Risk of Developing Chronic Graft-Versus-Host Disease One and Two Years Post-Transplantation of Cyclophosphamide and Non-Cyclophosphamide Patients

Ezra Schwartz, Staples High School

Improving Rotator Cuff Tear Diagnosis Using Deep Learning

Vito Scutari, King School

Comprehensive Assessment for Executive Dysfunction (CAED): A Gamified, Tablet-Based Clinical Evaluation Tool for Patients with Traumatic Brain Injury

Ashika Sharma, Rocky Hill High School

Identifying Psychiatric Disorder Risk Genes: Computational Multi-Omic Analysis of Gene Expression and Chromatin Accessibility Comparing Developing vs. Adult Prefrontal Cortex

Alissa Yang, Amity Regional High School

Developing a Drought Scale by Using Drought Stress Levels of Lip Ferns from Public Data in Southwestern U.S.

Ruohan (Grace) Ye, Ethel Walker School

Comparison of the Reused Horse Manure as a Source of Fertilizer to Original Fertilizer

Sofia Youssefi, Bridgeport Regional Aquaculture Science and Technology Education Center

Enhancing Lactobacillus acidophilus Molecular Responses with Hydroxyapatite to Stimulate Tooth Enamel Regeneration

The STEM Poster Exhibition will be online at <https://tinyurl.com/w6djendp>
password “STEM2026”, through February 28, 2026.



2026 Registered High Schools/Programs

ACES Chase Academy, Waterbury
Amity Regional High School, Woodbridge
Avon High School
Bloomfield High School
Bridgeport Regional Aquaculture Science and
Technology Education Center
Canterbury School, New Milford
Choate Rosemary Hall, Wallingford
Connecticut International Baccalaureate
Academy, East Hartford
Connecticut River Academy, East Hartford
CREC Academy of Aerospace and Engineering,
Windsor
CREC Academy of Science and Innovation,
New Britain
Darien High School
East Catholic High School, Manchester
East Granby High School
East Hartford High School
East Lyme High School
Engineering and Science University
Magnet School, West Haven
The Ethel Walker School, Simsbury
Farmington High School
Glastonbury High School
Global Experience Magnet School, Bloomfield
Greenwich Country Day School
Greenwich High School
Hall High School, West Hartford
Hamden Hall Country Day School
Hartford Public High School
Joel Barlow High School, Redding
Killingly High School
King School, Stamford
Kingswood Oxford School, West Hartford
Laurel Springs School (online), Ojai, CA
Lewis S. Mills High School, Burlington
Madina Academy, Windsor
Manchester High School
Norwich Technical High School
Ridgefield High School
Rocky Hill High School
Simsbury High School
The Sound School, New Haven
South Windsor High School
Staples High School, Westport
Thomaston High School
UConn Health's Health Career Opportunity
Programs (HCOP)
Weaver High School, Hartford
West Haven High School
Weston High School
Wilby High School, Waterbury
The Williams School, New London
Windham High School
Wolcott High School

SPONSORS

- Cato T. Laurencin Institute for Regenerative Engineering (UConn Health)
- Connecticut Academy of Science and Engineering
- Connecticut Science Supervisors Association
- Connecticut Science Teachers Association
- Connecticut Department of Public Health
- UConn Health/CT Area Health Education Center (AHEC)
- UConn Office of Undergraduate Admissions

DONOR (raffle prizes)

- Barnes & Noble at UConn Health, Farmington

COOPERATING ORGANIZATIONS

- Connecticut Science and Engineering Fair
- UConn College of Liberal Arts and Sciences
- UConn Department of Natural Resources
- UConn Office of Early College Programs
- UConn Graduate School of Biomedical Science
- UConn School of Dental Medicine
- UConn School of Engineering
- UConn School of Medicine
- Yale University

8 a.m. – 1 p.m.: UConn Health Barnes & Noble is open especially for CT HSSHS!

Take the stairs across from Massey Auditorium up one floor.

*Drop off your completed raffle entry (find it in your portfolio) at the bookstore by 12:25 for a chance to **win this blanket!***

(54" x 84", 80% polyester and 20% cotton, \$44.98 value)



ADVISORY COMMITTEE

- Jenna Bartley, PhD, UConn Health Department of Immunology, Center on Aging, Farmington
- Melissa Caimano, PhD, UConn Health Department of Medicine, Department of Pediatrics, and Department of Molecular Biology and Biophysics, Farmington
- Petra Clark-Dufner, MA, Program Director CT HSSHS, CT AHEC at UConn Health, Farmington
- Deborah Day, MS, Yale University, New Haven
- Kathi Ellison, MS, AT&T (retired)
- Joy Erickson, MS, Former Regional Director CT-JSHS, UConn, Storrs (retired)
- Sandra Justin, PhD, Connecticut Science Supervisors Association
- Brittany Knight, PhD, Site Director CT HSSHS, U.S. Association for the Study of Pain
- Frank LaBanca, EdD, Area Cooperative Educational Services, Waterbury
- John Listorti, MAT, Killingly High School, Dayville
- Richard Luddy, PhD, UConn Department of Physics, Hartford
- Jeff Orszak, MA, Executive Director, Connecticut Academy of Science and Engineering (CASE), East Hartford
- Victoria Schulman, PhD, King School, Stamford
- Eileen Stowe, MS, Thomaston High School
- Ralph Yulo, PhD, Eastern Connecticut State University, Willimantic

ADMINISTRATIVE TEAM

- Joanna Moon, CT AHEC
- Ellen Ravens-Seger, CT AHEC Administrative Program Coordinator
- Cathy Torrisi, CT HSSHS Communications

***APPLICATION REVIEWERS, JUDGES, MODERATORS,
URBAN HEALTH/AHEC SCHOLARS, GRAD STUDENTS, CT-JSHS ALUMNI,
AND ALL OTHER VOLUNTEERS:
THANK YOU!***

ABSTRACTS

Oral Presenters

A Comprehensive Method to Combat Antibiotic Resistance in Soil Microbes: Integration of CRISPR-Cas9 Gene Editing and Nanoparticles for Enhanced Biodegradation of Pollutants

Sahithi Aliminate

Engineering and Science University Magnet School, West Haven

Mentor: Kate Pippenger, PhD candidate, Yale University Earth and Planetary Sciences Department

Antibiotic resistance is a growing global threat, exacerbated by environmental pollutants that disrupt microbial ecosystems and increase selective pressure for resistant bacteria, particularly in wastewater systems. Despite advances in gene editing and nanotechnology, their combined application to simultaneously reduce resistance and enhance pollutant degradation remains unexplored. This study explores a dual approach using CRISPR-Cas9 gene editing and silver nanoparticles (AgNPs) to enhance bacterial biodegradation of bisphenol A (BPA), an endocrine-disrupting plastic pollutant, while reducing antibiotic resistance. It was hypothesized that CRISPR-modified bacteria, when combined with AgNPs, would exhibit enhanced BPA degradation, reduced resistance, and altered growth dynamics compared with unmodified strains.

Escherichia coli DH5 α was genetically modified using a CRISPR-Cas9 system targeting antibiotic resistance genes. Normal and CRISPR-modified strains were exposed to BPA and AgNPs, and growth, colony size, and BPA degradation were monitored over five days. ImageJ software quantified bacterial colony count and measured the percentage of plate coverage, while BPA degradation was analyzed using liquid-liquid extraction and mass spectrometry.

CRISPR-modified bacteria combined with AgNPs yielded the lowest amount of BPA remaining (area under the peak = 264), signifying enhanced degradation efficiency compared to other conditions. Furthermore, the modified strains formed larger, more abundant colonies, indicating enhanced growth and reduced antibiotic resistance, confirming successful bacterial gene modulation.

These findings suggest that CRISPR-Cas9 could be leveraged to combat antibiotic resistance while improving pollutant degradation, offering a scalable bioremediation strategy. Future research should optimize gene targets, assess long-term ecological impacts, and integrate this approach into wastewater treatment plants, bioreactors, and environmental initiatives.

Utilizing Organic Byproducts within the Internal Arrangement of Concrete to Enhance the Dimensional Stability and Durability of Porous Concrete

Emily Barnhart

Bridgeport Regional Aquaculture Science and Technology Education Center

Mentor: Kirk Shadle, Bridgeport Regional Aquaculture Science and Technology Education Center

Porous concrete is a type of concrete mixture that allows stormwater to be infiltrated and filtered, reducing the amount of runoff. Porous concrete, however, is vulnerable to freeze-thaw weather damage, leading to cracks and failure in the concrete structure. Organic byproducts added into the matrix of concrete are proposed to serve as a theoretical “pillow” to distribute the pressure caused by the freeze-thaw process within the matrix of the concrete. Readily available sustainable organic waste (SOW) products (banana leaves, avocado pits, and olive pits) are proposed to be supplemented into the concrete matrix to support the standard aggregate. The SOW is pulverized to a 4-5 mm and is supplemented into the matrix of concrete at the percentages of 5%, 10%, and 15%, in relation to aggregate. The concrete is then formed into 12.7 cm by 10.16 cm by 5.08 cm block molds. To determine the optimum SOW in the concrete matrix, a series of data points are evaluated: slump, porosity, density differential, and freeze-thaw resistance. Avocado pits at the percentage of 5% are the best candidate for porous concrete. Following the first round of the freeze-thaw cycle (soaking, freezing, and then drying), the avocado pits had an increased density of 2.70% after impacting the block with a force of 365.7 N. This means that instead of losing density after the initial freeze-thaw cycle and drop, it gained density from the freeze-thaw cycle. Compare this to the control block, which, after going through the freeze-thaw cycle, had a reduction in density of 43.10%, after being dropped with a force of 280.1 N. Avocado pits also have a quicker infiltration rate, with the infiltration rate being 21.01 seconds, a 3.9-4 seconds difference from the control, which had an infiltration rate of 24.95 seconds.

AI-Powered Gait Analysis for Early Detection of Alzheimer's Disease and Mild Cognitive Impairment

Rhea Doshi

Kingswood Oxford School, West Hartford

Mentor: Ashkan Novin, PhD, SequestBio

Background: Early detection of Alzheimer's disease (AD) remains a major clinical challenge, as current diagnostic methods are invasive, costly, and often identify the disease only after irreversible neurodegeneration. Increasing evidence suggests that gait dysfunction, particularly under dual-task conditions, emerges early in cognitive decline, reflecting disruption of motor-cognitive neural networks.

Objective: To develop and evaluate an artificial intelligence-driven, markerless gait analysis system for detecting early cognitive impairment associated with AD and mild cognitive impairment (MCI).

Methods: I developed NeuroStride, a computer vision platform to extract spatiotemporal gait features from standard walking videos. The Python-based analysis pipeline uses pose estimation, feature engineering, and supervised machine learning, trained on public datasets (AD Knowledge Portal, PhysioNet, NIAGADS). Following April 2025 IRB approval, prospective clinical validation was performed in 38 memory clinic participants, including a standardized cognitive assessment (MoCA). An XGBoost classifier, trained via stratified five-fold cross-validation, was used for gait classification. Recursive feature elimination identified key gait parameters, with performance evaluated by accuracy and correlation with MoCA scores.

Results: NeuroStride distinguished cognitively impaired participants from cognitively healthy controls with an accuracy of 91.2%. Recursive feature elimination identified dual-task stride-to-stride variability as the strongest predictive feature and demonstrated a significant negative correlation with MoCA scores.

Conclusions: Markerless gait analysis using standard video and machine learning demonstrates high diagnostic accuracy for early cognitive impairment. This noninvasive, scalable, accessible approach supports gait analysis as a functional screening tool for distributed brain network integrity in clinical, community, and home-based settings.

Vitamin D3 Supplementation Ameliorates Muscle Degeneration through Calcium Regulation in a Caenorhabditis elegans Model of Duchenne Muscular Dystrophy (DMD)

Nolan Francis

Staples High School, Westport

Mentor: Amy Parent, Staples High School

Duchenne Muscular Dystrophy (DMD) is a genetic disorder that causes progressive muscle wasting and weakness. This occurs because of mutations in the dystrophin gene, which is essential for maintaining the integrity of muscle cells (Association, 2025). DMD's impact extends beyond physical limitations, significantly burdening affected individuals and their families emotionally and financially. Vitamin D3 has a small positive effect on muscle strength determined via meta-analysis (Baudart, 2014), and vitamin D insufficiency is frequently observed in DMD patients (Bian, 2018); however, studies in DMD mouse models have reported inconclusive effects of vitamin D3 supplementation on muscle pathology and function (Debruin, 2019; Baudart, 2014). This prospective investigation evaluates the effects and mechanisms of vitamin D3 supplementation in a DMD *Caenorhabditis elegans* (*C. elegans*) model. In this model, vitamin D3 (0.1 μM -100 μM) improved locomotive behavior ($p < 0.04$ across groups), longevity (reduced hazard ratio by up to 10%), and reduced reactive oxygen species levels. Supplementation also significantly lowered mechanistic calcium accumulation in muscle cells as measured by a calcium reporter fluorescence assay (all tested concentrations $p < 0.05$ vs. control), but did not alter the kinetics of aldicarb-induced paralysis (log-rank $p > 0.45$ across groups). Collectively, these findings indicate that vitamin D3 may offer protective effects against muscle damage in DMD through muscular calcium regulation. These preliminary results suggest vitamin D3 could be an affordable strategy to improve muscle function and extend lifespan in affected individuals. Given its established safety, accessibility, and low cost, prospective vitamin D3 supplementation in DMD patients warrants further mammalian investigation to clarify long-term benefits, underlying mechanisms, and dose concentration.

Photocatalytic Degradation of Polypropylene via Iron-Modified Titanium Dioxide

Carolyn Hopstaken

Joel Barlow High School, Redding

Mentor: Paul Testa, Joel Barlow High School

Polypropylene (PP) is a primary contributor to persistent plastic pollution due to its high resistance to natural degradation. As plastic accumulates in the environment, effective and environmentally compatible degradation strategies are increasingly necessary. Photocatalysis has emerged as a promising approach, utilizing materials that produce reactive oxygen species (ROS) under light irradiation to initiate chain scission. While titanium dioxide (TiO_2) is an established photocatalyst, its efficiency is

fundamentally limited to ultraviolet light. This study investigated a $\text{TiO}_2/\text{Fe}_2\text{O}_3$ heterojunction to extend photocatalytic activity into the visible light spectrum by facilitating interfacial charge separation and enhancing the generation of ROS. Although Fe-doped titania has been studied for dye degradation, its application to polypropylene degradation has not been sufficiently explored, demonstrating a key knowledge gap in practical photocatalytic remediation. Iron-modified TiO_2 was prepared via mechanical grinding, applied to PP film, and subjected to 144 hours of controlled light irradiation. Surface degradation was investigated through contact angle goniometry and analyzed through Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy-energy dispersive spectroscopy (SEM/EDS) at IBM Research facilities. The most significant findings include a significant increase in hydrophilicity of the heterojunction samples compared to the unmodified TiO_2 samples post-irradiation, with a difference of contact angles over 10° . However, analytical limitations were observed: Transmission FTIR indicated that degradation remained surface-confined rather than bulk-penetrating, and SEM analysis was impacted by surface charging on the nonconductive polymer. Ultimately, this study serves as an introduction that necessitates further investigation and design modification to fully characterize and explore this degradation mechanism.

Utilizing Exfoliated Graphite for Oil Extraction from Spills via Autonomous Robotic Devices

Ravindu Karunaratne

Hamden Hall Country Day School

Mentor: Dr. Frank Gasparro, Hamden Hall Country Day School

Oil spills discharge substantial quantities of oil into marine environments, resulting in significant and sometimes irreversible damage to ecological systems and marine life if not addressed promptly. Thousands of spills occur annually in the United States alone, releasing large quantities of oil into marine environments, contaminating billions of gallons of water. Existing oil spill remediation methods are often costly, labor intensive, and inefficient, particularly in large or remote spill scenarios. This shows the need for affordable, environmentally friendly, and automated alternatives. Exfoliated graphite (EG) is hydrophobic, possesses a large surface area, and shows strong oil affinity, making it a promising yet underexplored material for oil cleanup systems. The primary research question we address is: *Can exfoliated graphite be used in an autonomous smart floating device to effectively absorb and recover oil from water surfaces under simulated spill conditions?* We primarily investigated the oil-absorption capacity of EG and then focused on retrieval methods. Then, we 3D-printed the devices, loaded them with EG cartridges, and demonstrated the feasibility of real-time, remote-controlled oil recovery. By using radio frequency and Wi-Fi communication, we tested navigation in simulated ocean conditions in a controlled fish tank environment. Our research demonstrated effective navigation and oil absorption, though the oil-retrieval method requires further refinement. Key findings demonstrate that exfoliated graphite exhibits high oil-absorption efficiency and that the remotely controllable device effectively navigates contaminated areas. Our results demonstrate the feasibility of combining EG with remotely controlled devices as a scalable, environmentally sustainable approach to oil spill remediation.

NeuroMirror: A Hebbian-Theory-Based EEG-Driven Mirror Therapy System for Post-Stroke Upper-Limb Rehabilitation

Sabrina Liu

Choate Rosemary Hall, Wallingford

Mentor: Shiyao Gu, Shanghai Yusi Computational Science Development Center

Stroke is a leading cause of long-term upper-limb motor impairment because it disrupts sensorimotor neural pathways, limiting patients' ability to regain voluntary function through conventional rehabilitation. This project addresses the need for therapies that both engage and measure underlying neural activity during training. NeuroMirror is a closed-loop "neuromirror" rehabilitation system that combines mirror therapy with real-time EEG monitoring to enhance Hebbian neuroplasticity. The central aim is to synchronize motor intention, sensory feedback, and visual input to strengthen residual sensorimotor connections. NeuroMirror comprises three integrated components. First, a 16-channel EEG system is engineered with high input impedance, low-noise amplification, and isolated digital-analog power to reliably capture sensorimotor rhythms. Second, a visual tracking module estimates the movement of the healthy hand and drives an intelligent rehabilitation glove to actively assist the impaired hand, transforming traditional passive mirror therapy into intention-driven bilateral training. Third, the system quantifies motor engagement by tracking event-related desynchronization (ERD) in the μ (8–12 Hz) and β (13–30 Hz) bands as neural markers of sensorimotor activation. In experiments, mirror vision with passive movement reduced μ - and β -band power by 67.7% and 74.5% relative to baseline, while adding explicit motor intention further increased μ -band ERD to 93.5%. These results indicate that combining visual input, proprioceptive feedback, and motor intention produces strong Hebbian effects and demonstrate that NeuroMirror can transform mirror therapy into an adaptive rehabilitation platform that reinforces neural activation during stroke recovery.

Development of a Novel Nanoparticle Drug-Delivery System Using OLAH Targeting to Deliver Surfactant Protein and Prevent Neonatal Respiratory Distress Syndrome

Tyler Malkin

Greenwich High School

Mentor: Andrew Bramante, Greenwich High School

Neonatal respiratory distress syndrome (NRDS) is the leading cause of death in premature infants, with over 1.4 million annual cases globally. The current preventative therapy for NRDS is corticosteroids, which are a systemic rather than targeted therapy and have several adverse side effects. Surfactant protein has shown great promise for prophylactic prevention of NRDS in high-risk infants, but there is currently no mechanism of delivery for prenatal treatment. This research developed SuPCO, a novel chitosan-coated poly lactic-co-glycolic acid (PLGA) nanoparticle loaded with surfactant protein that utilizes an oleoyl-ACP hydrolase (OLAH) targeting system to deliver surfactant to fetal lungs. The chitosan coating was used in SuPCO to provide reverse pH solubility, allowing the nanoparticles to release into lung epithelial fluid but not in amniotic fluid. SuPCO also utilizes OLAH antibodies to target the overexpression of OLAH protein in abnormal lung epithelial cells found in NRDS. Each coating stage of SuPCO was confirmed with attenuated total reflectance-Fourier transform infrared (ATR-FTIR) spectroscopy and dynamic light scattering, which showed particle size increase from 330nm to 1,170nm after chitosan and OLAH antibody coating. Dissolution of SuPCO as a function of decreasing pH provided evidence of survivability in the amniotic fluid environment (only 20% release) and degradation in the epithelial cell fluid environment (>60% release). To verify SuPCO's selectivity for OLAH overexpression, a commercial OLAH enzyme-linked immunosorbent assay (ELISA) kit was reengineered to include ATR-FTIR analyses. Results demonstrated selective binding of SuPCO to OLAH proteins, highlighting that the novel nanoparticle drug-delivery system provides a safer and more effective therapy to help prevent the millions of global NRDS cases.

A Voice-Controlled Robotic Arm for Assisting Complex Surgical Tasks

Dillon Maltese

King School, Stamford

Mentor: Sarah Cha, MBA/MS, NewYork-Presbyterian/Weill Cornell Medical Center

In the U.S., there are over 250,000 annual deaths attributed to medical errors, with over 4,000 involving surgical accidents. While current robotic surgery has advanced precision in the operating room, nearly all current systems rely on a master-slave control system, requiring surgeons to manipulate the robot through a hand-operated console. As augmented reality (AR) is integrated into the operating room to enhance precision, it also increases a surgeon's cognitive load, especially when manually manipulating tools like an ultrasound probe, which is crucial for AR-guided procedures. To combat this, I developed a voice-controlled robotic arm to serve as an additional "hand," reducing multitasking while keeping a surgeon focused on the procedure. This device aims to aid surgeons by assisting with tasks that need to be completed, rather than replacing the surgeon's hands. The device was 3D modeled, was machined in aluminum, and is driven by NEMA stepper motors coupled to harmonic drives for high torque and low backlash. In motion-control and stability tests, the robotic arm demonstrated accurate, repeatable motion with responsive, real-time voice activation. Clinical feedback at Weill Cornell Medical Center has shown strong potential to improve ultrasound handling and similar precision-based tasks, with benefits in efficiency and concentration. Ongoing work aims to develop a claw, expand the task library, and implement the device across numerous surgical scenarios. By pairing AR with autonomous robotic manipulation, this system moves beyond traditional robotic surgery, creating a more intuitive assistant that offers a pathway to safer, more efficient, and cognitively lighter surgery.

Integrating Copy Number Alterations and Transcriptomics with Machine Learning Improves Survival Prediction in HPV-Negative Head and Neck Cancer

Vishnu Mukku

Avon High School

Mentor: Pranav Narnur, PhD candidate, Boston University Medical Center

HPV-negative head and neck squamous cell carcinoma (HNSCC) has a five-year overall survival rate of 48%. Survival prediction models can identify high-risk patients who might benefit from intensified treatment regimens. However, the performance of these models is limited by their reliance on only clinical features or single-omic data. This project aims to train and validate a machine-learning model integrating RNA-sequencing and somatic-copy-number-alteration data with clinical information to improve overall survival prediction for HPV-negative HNSCC. The training approach employed the random survival forests (RSF) model with block-constrained univariate feature selection and hyperparameter tuning. Three classes of RSF models were compared: clinical-only, omics-only, and combined (clinical + omics). The training dataset was The Cancer Genome Atlas (TCGA) cohort (n = 390), and the test set was the Clinical Proteomic Tumor Analysis Consortium (CPTAC) cohort (n = 104). The use of the

CPTAC data for validation assesses the model's generalization capabilities. Test set concordance indices (a measure of how well a model predicts relative ordering of survival time) were as follows: 0.538 for the clinical-only model, 0.626 for the omics-only model, and 0.664 for the combined clinical + omics model. Pathway enrichment analysis of the combined model's 74-gene signature revealed that survival prediction is driven by serine protease activity and extracellular matrix remodeling. These findings demonstrate that integrating multi-omics data for survival prediction significantly outperforms clinical staging alone and reveals survival-associated pathways, offering a more robust framework for risk stratification in HPV-negative HNSCC.

Developing a Fast-Response Aerosol Optical Depth Monitor for Continuous Information on Ambient Particulate Matter

Armaan Shrivastav

Amity Regional High School, Woodbridge

Mentor: Dr. Chong Qiu, University of New Haven

Fine particulate matter (PM) poses serious health and environmental risks. Because PM scatters and absorbs light, aerosol optical depth (AOD), which measures light scattering and absorption, can estimate PM levels. However, current AOD sensors are limited by dependence on sunlight and slow response times, highlighting the need for a faster sensor that can provide continuous, real-time PM data. The purpose of this project was to design and develop a rapid-response AOD monitor for real-time and continuous monitoring of ambient particulate matter. The original sensor design was altered using Tinkercad to reduce the dimensions of the main aperture (in the center of the sensor) and sampling tube. A 3D printer printed the new prototype, which was used along with a lux sensor at its bottom to measure the luminosity change due to the presence of aerosols from incense sticks that were pulled in by an air pump attached to the side of the sensor, and an LED light at its top. Two prototypes were tested, and AOD values were calculated after experimentation. The data for both prototypes were statistically significant ($r^2 > .95$); however, neither met the 20-minute stabilization criterion, and percent luminance changes of under 5% indicated insufficient responsiveness to increased aerosol concentrations. Chamber size, uneven aerosol distribution, and sensor limitations likely restricted rapid stabilization and accurate measurements. The findings provide a clearer understanding of how chamber design and particle distribution influence stabilization time and accuracy, establishing a foundation for faster real-time air-quality monitoring to improve public awareness.

Developing a Bio-Hybrid Luminescent Solar Concentrator Using Carbon Quantum Dots, Natural Fluorophores, and Kaolin Powder for Enhanced Solar Energy Harvesting

Aryan Shrivastav

Amity Regional High School, Woodbridge

Mentors: Dr. Jasna Jankovic and Antigoni Konstantinou, PhD candidate, University of Connecticut Department of Materials Science and Engineering

Luminescent solar concentrators (LSCs) are transparent devices designed to improve solar-cell efficiency by absorbing ultraviolet (UV) light and re-emitting it at visible wavelengths, which are more effectively used by photovoltaic cells. This research investigates low-cost, bio-hybrid LSCs as a potential solution for transparent, building-integrated solar technologies. While many LSCs rely on expensive or toxic materials, there is a gap regarding the effectiveness of affordable, biologically derived alternatives. The aim of this study was to evaluate whether bio-hybrid materials could enhance solar-cell output while maintaining optical transparency. Twenty-one epoxy slabs ($10 \times 10 \times 0.5$ cm) were fabricated across seven experimental groups, including a control, using carbon quantum dots (CQDs), chlorophyll, curcumin, and kaolin embedded in an epoxy matrix. Optical performance was measured using average visible transmittance (AVT), while electrical performance was assessed through current and maximum power output from edge-mounted solar cells. Statistical analysis was conducted using one-way analysis of variance (ANOVA) with Tukey's honestly significant difference (HSD) and Dunnett's post-hoc tests. Results showed that slabs containing CQDs and chlorophyll increased electrical power output by approximately 30% compared to the control, with minimal loss of transparency, indicating effective UV-to-visible downshifting. In contrast, curcumin- and kaolin-based slabs reduced performance due to increased light scattering and optical losses. These findings suggest that CQDs and chlorophyll are promising materials for low-cost, transparent photovoltaic applications. These results support the feasibility of scalable, eco-friendly LSCs for next-generation energy-efficient building design.

Assessing the Effects of Equine Grazing Muzzles on Upper Incisor Length and Dental Qualities in Ponies

Marilyn Sommerville

King School, Stamford

Mentor: Dr. Ronald J. Emond, Candlewood Equine

Grazing muzzle usage in ponies is a common management strategy to reduce forage intake on pasture and decrease risk of obesity and laminitis. Though grazing muzzles are effective and preserve regular equine behaviors, they may compromise other aspects of welfare, including the equine dentition. Though 17% of horse owners reported muzzle-induced damage to their equine's dentition in a survey, this subject area has never been researched. Thus, this study aimed to determine the effects of three equine grazing muzzles on incisors and the dentition in ponies. Pony 1, Pony 2, and Pony 3 were equipped with grazing muzzles of soft, medium, and hard base material, respectively. Muzzled ponies grazed on pasture for approximately six hours daily for 19 weeks. Upper incisors were measured regularly throughout the study. Muzzles were tested with force to determine relative material rigidity. Results indicated that Pony 1 experienced an average increase in incisor length, while Pony 2 and Pony 3 experienced an average decrease in incisor length. The increasing hardness of muzzle base material was directly proportional to increasing incisor wear. Overall, grazing muzzle usage decreased incisor length by an average of 0.0965 millimeters per week. The study found that grazing muzzles have the potential to impact the dentition in ponies and recommends using a grazing muzzle with a flexible, soft base material to minimize incisor wear. Understanding the dental effects of equine grazing muzzles will help horse carers make informed, case-specific decisions to manage their horses' health issues and promote greater animal welfare.

Experimentation and Application of Nutrient Additives to Enhance Resilience of Coral Reefs against Climate Change

Lucia Vivanco

King School, Stamford

Mentor: Dr. Loretta Roberson, Marine Biological Laboratory (MBL)

Coral reefs and seaweed are critical ecosystems that regulate global biodiversity, carbon cycling, and shoreline protection, yet both are experiencing devastating decline due to climate change. More than 75% of coral reefs are currently threatened, and projections estimate that 99% will experience mortality if global temperatures rise by just 2°C. The collapse of these foundational species would destabilize marine food webs and reduce oceanic carbon sequestration, with catastrophic global consequences. To address this, the present study investigates the use of engineered nutrient-infused tiles to promote the health of *Astrangia poculata* and *Sargassum filipendula*. Experimental tiles were developed with varying porosities and coatings, including general additives, manganese, multivitamins, and uncoated controls. Each treatment group was maintained in flowing seawater for four weeks, during which growth rates and photosynthetic efficiency were recorded weekly using weight measurements and pulse-amplitude modulated (PAM) fluorometry, while coral symbiont density was quantified via microscopy. Results showed limited benefits of nutrient-infused tiles for *Sargassum filipendula*, but significant improvements for *Astrangia poculata*, specifically higher symbiont densities than controls, suggesting that manganese strengthened the complex symbiotic relationship between corals and their zooxanthellae. These findings highlight the potential of additive-coated substrates as a novel and practical strategy for reef restoration, as strengthening this relationship would, by extension, prevent bleaching events. By integrating ecological insights with engineered materials, this research provides a framework for mitigating the effects of climate change on marine ecosystems. In the future, I hope to conduct field application tests and collaborate with offshore wind turbine companies to implement these substrates.

Investigating the Functional Role of Heterodimeric and Homodimeric Erythropoietin Receptor in Megakaryocytic-Erythroid Fate

Mariam Welbeck (group project with Farah Shahab)

Connecticut IB Academy, East Hartford

Mentor: Vanessa Scanlon, PhD, UConn Health Center for Regenerative Medicine and Skeletal Biology

Erythropoietin (EPO), secreted by the kidneys in response to hypoxia, stimulates erythropoiesis by binding to homodimeric and heterodimeric receptors on erythroid progenitors, promoting their proliferation and differentiation. Over five million anemic patients in the United States receive EPO to manage chronic anemia. However, EPO also acts on non-erythroid lineages, namely platelets, by binding to two-part receptors, homodimeric and heterodimeric, increasing risks of thrombosis and stroke. To improve EPO-based therapies, we investigated EPO signaling in megakaryocyte-erythroid progenitors (MEP), capable of differentiating into erythroid or megakaryocytic lineages. From a large screen, we identified two polypeptides that selectively agonize either the homodimeric or heterodimeric receptor, EBC-516 and ELI-3, respectively. We utilized these agonists in MEP and evaluated their effects using colony-forming unit assays to assess survival, proliferation, and lineage differentiation. We hypothesized that the homodimeric agonist would promote MEP and erythroid survival and differentiation, while the heterodimeric agonist would support MEP expansion without driving erythropoiesis. In vitro expanded MEP showed significantly

reduced colony-forming efficiency compared to unexpanded; EPO partially rescued this defect, whereas both the heterodimeric and homodimeric agonist fully restored colony formation. These results indicate that EPO supports MEP survival and colony formation through homodimer and heterodimer receptors. Ongoing studies aim to dissect the distinct contributions of EPO receptor subtypes in MEP biology to develop selective erythropoietic agonists that minimize off-target effects and improve safety in patients with chronic anemia.

Developing a Quantitative Method to Minimize Personal Bias within Taxonomic and Phylogenetic Interpretations of Precambrian Disc Fossils

Leonard Yeh

Amity Regional High School, Woodbridge

Mentor: Gregory Burzynski, PhD, University of the Virgin Islands

Disc fossils are a common fossil from the Cryogenian Period (720–635 million years ago). They are cyclic and radial fossils that are tethering structures of frondose organisms; their simplistic nature creates obscurity when researching them. Studies have attempted to categorize disc fossils solely using qualitative methods of interpretation, which are influenced by personal bias. This project aims to minimize bias in taxonomic/phylogenetic interpretations of Precambrian disc fossils by developing a method to describe the morphologies quantitatively. If this quantitative method works, then discrete grouping of fossils should occur rather than a scattered model because of patterns among shared morphological features. This process involves quantifying various common, predetermined features from 3D scans collected by the mentor. Data from each specimen were input into PAST 5.3 for principal components analysis (PCA). A similar process was repeated for various modern-day, natural circular patterns. Analysis showed significant grouping occurs when interpreting Precambrian discs; in contrast, modern specimens show a scattered model. Data suggest that the quantitative method works well for simple specimens from the Precambrian. Additionally, data significance supports this, since among the Precambrian specimens, the p-value was on a smaller scale than when incorporating modern species. This method could be applied to studies regarding fossils with simple morphologies, and future research could focus on testing this method on various time periods and species.

Poster Presenters

Assessing the Effectiveness and Performance of Adaptive Authentication in Isolation against Volumetric DDoS Attacks

Christopher Alvarado

Joel Barlow High School, Redding

Mentor: Paul Testa, Joel Barlow High School

A distributed denial of service (DDoS) attack is a cyberattack where a malicious actor generates large volumes of network traffic that slow vital processes, such as login pages. Although adaptive authentication has been shown to improve security, modern implementations often rely on transfer learning and machine-learning models trained on historical datasets, which can be costly and resource-intensive due to AI training. This study evaluates the standalone effectiveness of a rule-based adaptive authentication system against volumetric DDoS attacks by identifying behavioral metrics—IP addresses, location patterns, device and browser information, login speed, and request frequency—that distinguish bots from human users. A simulated login environment was constructed in Python, with DDoS behaviors generated using Locust and human behavioral statistics from Freeman et al. used to model legitimate traffic. Three trials were conducted: Trial 1 collected baseline traffic during a simulated DDoS attack without adaptive authentication; Trial 2 introduced a dynamic risk-scoring system; and Trial 3 refined parameter thresholds to balance detection accuracy and accessibility. Results showed that Trial 1 denied only 2.48% of bot requests despite artificial traffic, demonstrating limited protection. Trial 2 increased bot denials to 8.84% while raising human-user denials to 18.64%, indicating conflicts between security and usability. Trial 3 achieved 97.31% bot denials, showing improvement in attack mitigation, though stricter thresholds increased human-user denials to 50.41%. Overall, findings suggest that dynamic risk scoring based on behavioral metrics can strengthen DDoS defense without costly machine-learning systems, but refinement is needed to maintain accessibility for legitimate users.

Functionalizing DNA Nanotechnology: Optimizing the Impact of Buffer Conditions on Chemical Ligation

Claire Chan

Darien High School

Mentor: Mara Jaffe, Structural DNA Nanotechnology Lab, Department of Chemistry, New York University

The field of DNA nanotechnology removes DNA out of its biological context and instead utilizes DNA as a building block to form 2D and 3D structures with a wide variety of applications, ranging from nanoelectronics to medicine. Ligation of DNA plays a crucial role in assembling DNA crystals, providing stability to the construction of otherwise fragile structures that are sensitive to changes in pH and temperature. 1-ethyl-3-(3-dimethylamino(propyl)) carbodiimide (EDC) shows promise as an alternative to DNA ligation in nanoscale environments where alternatives, such as sticky-end cohesion and enzymatic ligation, remain impractical. Previous studies have shown success of EDC ligation between DNA-protein cocrystals; however, EDC ligation for double-stranded DNA strands (dsDNA) remains unpredictable, with as low as 30% efficacy. ImageJ was used for the densitometry analysis of ethidium bromide-stained polyacrylamide gels to investigate EDC ligation efficacy of different dsDNA reaction conditions, including pH, buffer concentration, temperature, and additional EDC buffer additions. It was found that EDC can ligate dsDNA, demonstrating novel potential for building robust DNA nanostructures. The reaction was found to occur most optimally at higher temperatures and a lower pH and buffer concentration, with its efficacy optimized to nearly 100%. The results of this proof-of-concept study provide insight into EDC's efficacy for the ligation of dsDNA and the optimization for the reaction for potentially assembling more diverse 2D and 3D DNA nanotechnologies.

Convolutional Neural Network Classification of DaTSCAN Images for Parkinson's Disease with Interpretability Analysis

Mary Chickering

Greenwich Country Day School

Mentor: Dr. Nathan Haag, Greenwich Country Day School

Parkinson's disease (PD) is a progressive, neurodegenerative disorder characterized by dopamine loss in the striatum, leading to common motor symptoms such as tremors, rigidity, and bradykinesia. DaTSCAN SPECT (dopamine transporter scan single-photon emission computed tomography) imaging has become increasingly used to visualize dopamine transporter activity and help distinguish PD from other movement disorders. Even so, scan interpretation can vary among experts, motivating the development of more consistent automated tools. This study aims to develop an interpretable dual-input convolutional neural network (CNN) to classify PD using standardized DaTSCAN images from the Parkinson's Progression Markers Initiative (PPMI). Preprocessed projection images and auto-selected axial-slice images are passed simultaneously through a shared, ImageNet-initialized EfficientNet-B0 feature extractor. The extracted features are combined and passed through a small

classification head with dense layers, dropout, and a sigmoid activation function to generate a PD vs. non-PD prediction. Performance is evaluated using ROC-AUC (receiver operating characteristic curve-area under the curve), accuracy, sensitivity, and specificity. The results are also compared against a logistic regression baseline. Interpretability is assessed using Grad-CAM (gradient-weighted class activation mapping) and occlusion testing, which demonstrate that the network focuses on biologically relevant features. The model achieved an AUC of 95.5% and an accuracy of 90.7%, suggesting that interpretable dual-input CNNs can be used as a tool to enhance consistency in PD imaging assessment. Unlike alternative diagnostic approaches, such as clinician evaluation of DaTSCAN images and clinical motor assessments, this method is intended to support classification rather than a stand-alone diagnostic system.

Development of a Crustacean β -chitin Biopolymer with Improved Functional Stability and Enhanced Decomposition

Campbell Saul Cohen

Bridgeport Regional Aquaculture Science and Technology Education Center

Mentor: Kirk Shadle, Bridgeport Regional Aquaculture Science and Technology Center

Around 368,000,000 tonnes of plastic was produced in 2019. It is estimated that around 90.4% of plastics produced in 2023 were fossil based, while only 0.7% of plastics produced were bioplastics. The largest type of plastic being produced is packaging, with container plastics comprising 14.5 million tonnes being produced in 2018. Development of higher bioplastics share is essential to the future sustainability of waste accumulation. It is proposed to produce a chitosan-based bioplastic which exhibits high temperature resistance, high tensile strength, and high biodegradability. To accomplish this proposal, chitin was mixed with sodium hydroxide to make water-soluble chitosan. A mold was made out of silicone for casting the final product. This chitosan product will be dissolved at 1% chitosan in 1% acetic acid (w/v) at room temperature. Triplicate trials add 2%, 3%, 10% of glycerol (v/v) to develop the bioplastic matrix. Variables tested for will include biodegradability, tensile strength, and heat resistance. Future applications could include uses as thinner or thicker food packaging or smaller plastic parts. This chitosan procedure produced 2.5 grams of chitosan with a percent yield of 37.88%.

Microneedle-Contact Lens Co-delivery of Azobenzene-Liposome Photoswitches and PEDF Neurotrophic Growth Factors to Repair the Effects of Macular Degeneration

Hannah Dcruz

Greenwich High School

Mentor: Andrew Bramante, Greenwich High School

Age-related macular-degeneration (AMD) is a leading cause of blindness, caused by the deterioration of photoreceptors in the macula. Currently, there are no methods to restore lost vision, and AMD drug-delivery mechanisms are costly and require a topical anesthetic. Recently, photoswitches have attracted attention as an ocular therapeutic for their unique ability to change shape in response to light, allowing them to serve as substitute photoreceptors. Pigment epithelium-derived factor (PEDF) is a growth factor that could potentially inhibit degeneration if restored in AMD patients. This research produced a new therapy for AMD that will effectively deliver PEDF and azobenzene, a common photoswitch, in a liposome to slow degeneration and restore lost vision, with delivery through the conjunctiva-sclera route via microneedle-embedded contact lenses. Liposomes were first fabricated via modified-ethanol injection, followed by loading of PEDF. Half of the liposomes were then encapsulated with DOPE, a fusogenic lipid. From here, all liposomes were embedded with azobenzene, creating PEDF-azobenzene liposomes and DOPE-PEDF-azobenzene liposomes, and their photoswitchable properties tested using fluorescence microscopy. This was followed by the attachment of kainate and glutamate ligands to DOPE-PEDF-azobenzene liposomes and N-methyl-D-aspartate (NMDA) ligands to PEDF-azobenzene liposomes, confirmed by high-performance liquid chromatography (HPLC). GALA was then added to the DOPE-PEDF-azobenzene liposomes to enhance fusogenic properties, before formulating drug-hydrogel solutions for microneedles. Finally, microneedles were fabricated using the vac-and-fill method, and their penetration abilities tested on a porcine sclera using HPLC. This demonstrated that the needles have 96% dissolution in under 10 minutes, highlighting their exceptional and efficient release properties. This new ocular delivery system that is both noninvasive and topical will allow for improved care accessibility for patients and inhibit the effects of AMD.

The Effect of Polyphenols and Ascorbic Acid on Iron Absorption in Zophobas morio

Eva Figlar

Ridgefield High School

Mentor: Dr. Daniel Baluha, Western Connecticut State University

Iron is proven to be affected by the consumption of polyphenols and ascorbic acid. Polyphenols inhibit the absorption of iron because they chelate to the iron molecules, making them larger and therefore more difficult for epithelial cells to absorb.

Polyphenols are found in foods such as fruits, vegetables, grains, and nuts. Ascorbic acid enhances the absorption of iron because the ascorbic acid donates an electron to iron, making it into the only form that can be absorbed. This experiment looks at how different ratios of ascorbic acid and polyphenols can impact the amount of iron absorbed in mealworms, to maximize the nutrition potential for people living in developing countries with minimal access to other forms of iron, such as red meat. This experiment used oats and spinach as the iron variable, red leaf lettuce as the polyphenol variable, and arugula as the ascorbic acid variable, and measured iron quantities in superworms using atomic absorption spectrometry. It was determined that moderate (2g) amounts of polyphenols inhibit iron and ascorbic acid enhances iron absorption when consumed with polyphenols.

A Novel Dual-Targeting Therapeutic Patch for Non-addictive, Non-opioid Pain Suppression via Selective Transient Receptor Potential (TRP) Modulation

Nishant Jain

Greenwich High School

Mentor: Andrew Bramante, Greenwich High School

Chronic pain afflicts over 100 million Americans—more than diabetes, depression, and hypertension combined. However, analgesic therapeutics have remained stagnant for decades. Existing non-opioid treatments carry substantial toxicity, while opioid-based therapies have fueled one of the deadliest public health emergencies, claiming 110,000 overdose deaths in 2023 alone. This research introduces a novel, non-addictive, smart transdermal delivery system (TDS) that silences pain at its molecular origin—delivering sustained, localized pain control at a fraction of the cost of conventional therapies.

Pain begins in the peripheral nervous system, where transient receptor potential (TRP) ion channels on sensory neurons detect thermal and chemical stimuli and trigger ion influx that transmits pain signals to the brain. Rather than suppressing pain centrally—which carries addiction risk—this treatment targets TRP channels at their source. *Euphorbia bicolor* latex desensitizes TRPV1 receptors and suppresses release of pain-signaling neuropeptide CGRP, while *Acmella oleracea*'s spilanthol modulates TRPA1 and antagonizes TRPV1, collectively reducing sensory neuron excitability without central pathway involvement.

Chemical characterization via HPLC-Vis/DAD (high-performance liquid chromatography with diode-array detection) and ATR-FTIR (attenuated total reflectance-Fourier transform infrared spectroscopy) confirmed bioactive constituents, including resiniferatoxin (RTX). Efficacy was evaluated in GCaMP6s-expressing *Drosophila melanogaster*, where TRP-driven calcium influx produces neuronal fluorescence. Treated flies exhibited a 53% reduction in fluorescence intensity and a 46% increase in climbing past a 40°C heat barrier, confirming analgesia. Scanning electron microscopy assessed structural neuroprotection after TRPA1 agonist exposure. Transdermal delivery was demonstrated using a Franz diffusion cell.

This novel approach to peripheral TRP channel silencing offers a non-addictive, cost-accessible analgesic strategy with direct translational relevance to medicine's most intractable crises.

Simulating Droplet Breakup in Obstacle Arrays Using the Deformable Particle Model

Nicholas Lu

Amity Regional High School, Woodbridge

Mentor: Corey O'Hern, PhD, Yale University

Droplets flowing through quasi-2D obstacle channels were modeled using the deformable particle (DP) model, wherein droplet surfaces are represented as polygons with particles at the vertices whose positions and velocities serve as the relevant degrees of freedom of the system. These surface particles interact via a "shape-energy" contribution to the total potential energy, which consists of spring-like bonds between adjacent vertices, akin to surface tension, and a non-local term capturing the effect of the internal fluid effect by effectively imposing conservation of the droplet area. Current DP simulations have only been implemented for droplet breakup involving collisions of singular droplets with singular obstacles, as opposed to multi-obstacle arrays present in experiments. The study's purpose is to address this gap by performing large-scale simulations of droplet breakup in obstacle arrays to understand the effect of array properties on the size distribution of daughter droplets emerging from the obstacle array. We observed that smaller obstacle sizes and spacings resulted in faster decreases in droplet size, along with greater size decreases overall over the course of the simulations. Studies are underway to further characterize the relationship between droplet size and obstacle size and spacing, along with investigating other obstacle properties' impacts. Insights gained from our work help perform efficient and realistic computational modeling of microfluidic devices, which can allow us to test them over wide ranges of design parameters, without the need for physically creating each prototype device. This can vastly reduce the design time and material costs associated with manufacturing these prototypes.

Optimizing Bus Fleet Allocation in Mid-sized Cities Using Mixed-Integer Nonlinear Programming: A Case Study in Stamford, CT

Victoria Makarov

Laurel Springs School, Ojai, CA (online)

Mentor: Vera Ulanovskaya (parent/guardian)

Public bus systems in mid-sized cities often struggle to balance constrained operational resources with serving time-varying passenger demand and multimodal travel patterns. In Stamford, Connecticut, a fleet of 40 buses must be allocated across 20 routes with rapidly shifting levels of passenger demand throughout the day while aligning with train arrivals at the Stamford Transportation Center (STC). The city's strategic plan "STAMFORD 2035" prioritizes reducing bus headways and strengthening multimodal connectivity; however, traditional scheduling tools—largely based on linear or heuristic formulations developed in the 1990s—struggle to capture the nonlinear, time-dependent interactions inherent to real transit operations. This study introduces a mixed-integer nonlinear programming (MINLP) framework for optimizing bus allocation across routes and time blocks, applied in this case study to nine consecutive two-hour periods from 5:00 a.m. to 11:00 p.m. The algorithm incorporates route-specific passenger demand, traffic-adjusted loop durations, fleet constraints, and mandatory synchronization with STC train arrival windows. When tested on four weeks of real ridership data, the optimized schedules significantly outperformed CTtransit's current system: Average bus headways decreased by over 35%, alignment with train arrivals at the STC increased by over 90%, and fleet utilization only went up by 6%. Sensitivity analysis also showed how policy-relevant trade-offs between operational cost and service quality are made via prioritization weights. Overall, this MINLP approach provides a computationally traceable and scalable tool for data-driven transit planning in resource-constrained transit systems, allowing for future extensions to incorporate additional operational constraints and real-time parameter adjustment.

Optimizing the Efficiency of Solar Panels Using Enhanced Cooling Techniques

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Solar panels are the fastest-growing source of renewable energy. Despite rapid expansion, most panels only convert about 17% of solar energy into electricity. Conversion efficiency declines further under elevated operating temperatures. Conventional photovoltaic systems lack integrated thermal-regulation strategies to stabilize electrical output under sustained heat exposure. This research presents a thermally optimized hybrid cooling configuration integrating passive and active cooling to enhance photovoltaic voltage stability under heat stress.

It was hypothesized that increasing the surface temperature of the panel would decrease voltage output, whereas implementing cooling methods would increase voltage. To test this, the investigation examined how thermal variation affects electrical performance. Four different conditions were tested: a control without cooling, a passive heat sink, an active thermoelectric cooler, and a combined heat sink and thermoelectric configuration. Temperature-controlled units were utilized to simulate conditions ranging from 15°C to 40°C. Voltage and temperature were monitored over 10-minute intervals. Results showed that as panel temperature increased, the control condition exhibited a voltage decrease of approximately 8–12%. In contrast, the passive heat sink increased voltage by about 5%, the thermoelectric cooler by roughly 9%, and the combined configuration by up to 13% under identical heat stress.

Future advancements will incorporate copper-heat-sink modifications to enhance the novel thermoelectric cooler and heat sink configurations. This research sets a new convention in modern renewable energy systems by improving the efficiency, cost effectiveness, and the weather dependency, paving the way for real-world applications.

CX3CR1⁺ Cell Type-Specific ERK Hyperactivation Promotes Inflammatory Remodeling

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Alzheimer's disease (AD) is the most common neurodegenerative cause of senile dementia, affecting more than 55 million patients worldwide. Recent studies have shown that immune signaling pathways play central roles in neurodegenerative disorders, driving chronic inflammation and neuronal dysfunction. In particular, dysregulated extracellular signal-regulated kinase (ERK) activation has been linked to the emergence of disease-associated microglia, which regulate pro-inflammatory immune responses in AD. Importantly, microglia and other myeloid populations express the chemokine receptor CX3CR1; however, the

effects of sustained ERK hyperactivation in CX3CR1⁺ cells on immune remodeling remain unclear. We hypothesized that ERK hyperactivation would distinctly impact the proteomic phenotypes of CX3CR1 cells, causing systemic inflammation. To elucidate this, we generated a novel BRAFV600E mouse model that induces chronic ERK hyperactivation specifically in CX3CR1⁺ cells. Using quantitative proteomic profiling of spleen tissue, we analyzed peripheral immune responses under baseline and lipopolysaccharide (LPS)-induced inflammatory conditions. At baseline, ERK hyperactivation significantly altered the expression of interferon-stimulated proteins ($p < 0.05$), indicating innate immune priming. Following LPS challenge, ERK hyperactivation amplified inflammatory remodeling, with hundreds of differentially expressed proteins and marked upregulation of translational and cytokine-associated pathways, alongside suppression of homeostatic immune processes. Because peripheral immune dysregulation can prime microglia and promote neuroinflammation, these findings establish a mechanistic link between systemic ERK-driven immune remodeling and inflammatory pathways implicated in AD. Together, this work identifies ERK hyperactivation in CX3CR1⁺ myeloid cells as a key driver of inflammatory imbalance and highlights ERK signaling as a promising therapeutic target in mitigating AD progression.

Blue Oyster Cult(ure): Using Pleurotus for Mycoremediation of Water Contaminants

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Mentor: Kaitlin McKale, Norwich Technical High School

Microplastics have been found in all bodies of water across the world, including freshly fallen snow in Antarctica and deep ocean trenches. Although studies on the effects on human bodies are limited, studies have shown that microplastics are linked to cancer, heart attacks, inflammation, and infertility. Despite their rise to popularity in the 1950s, little research has been done on ways to mitigate their contamination of drinking water. This study investigates the use of blue oyster mushrooms as an all-natural and affordable filter. Blue oyster mushrooms (*Pleurotus ostreatus*) are known for their ability to break down complex organic pollutants. Whole and partial mushrooms were grown in water containing 1g of microplastics to determine if there is an optimal part of the mushroom that should be used for filtering. Observations showed the mushroom cap removed the greatest quantity of microplastics over one week trial. Although additional studies are still needed, these results suggest that blue oyster mushroom caps are an ideal choice for the remediation of microplastics in drinking water. Blue oyster mushrooms not only remove microplastics from water, but they transform them into harmless compounds, which makes them suitable for water filtration.

Investigating the Role of Epigenetic Regulation on Primary Human Megakaryopoiesis

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Hematopoietic stem and progenitor cells (HSPCs) generate all blood lineages through regulated differentiation programs in the bone marrow. Disruption of this process contributes to disorders like anemia, thrombocytopenia, and leukemia. Epigenetic regulators are critical in guiding lineage commitment, and lysine-specific demethylase 1 (LSD1) has emerged as an important modulator of hematopoietic differentiation. However, its functional role in megakaryocytic lineage dynamics remains poorly defined. Megakaryocytes (Mks) produce platelets, and defects in their development can lead to disorders like thrombocytopenia. To determine how LSD1 inhibition alters megakaryocytic progenitor behavior, we performed seven-day single-cell time-lapse imaging of megakaryocyte-erythroid progenitors (MEPs) in conditions permissive of megakaryocyte differentiation. Cells were computationally tracked to generate lineage trees, quantify division timing, lifespan, and migratory behavior under control and LSD1-inhibited conditions. LSD1 inhibition altered early progenitor kinetics. LSD1-inhibited cells reached a higher average generation (control: 2.33 ± 0.26 ; experimental: 4.12 ± 0.20 ; $p < 0.00001$), indicating increased proliferative capacity. Additionally, LSD1i cells exhibited a faster division rate (control: 284.17 ± 60.16 frames; experimental: 157.47 ± 14.24 frames; $p < 0.05$), suggesting accelerated division kinetics. Total migration distance was also significantly reduced in LSD1-inhibited cells (control: $1,578.36 \pm 308.86$ pixels; experimental: 595.11 ± 64.36 pixels; $p < 0.01$). These findings indicate that LSD1 inhibition reshapes early megakaryocytic progenitor behavior by modulating both division timing and migration dynamics. The behavior shows a bias toward megakaryocyte differentiation highlighting a role for LSD1-mediated epigenetic regulation in governing megakaryocyte lineage dynamics.

A Sustainable Treatment for Heavy Metal Pollution: Adsorption and Desorption of Ni(II) Ions in Water Using DNA-Wrapped Carbon Nanotubes

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Mentor: Dr. Simon Vecchioni, New York University

As of 2024, one in four people globally lack access to safe drinking water. According to the United Nations (UN), in 2021 over 40% of 75,000 bodies of water in 89 countries were found to be severely polluted. As a result, it is imperative to develop efficient, sustainable, and cost-effective solutions for wastewater treatment. Adsorption, the physical/chemical adherence of pollutants onto a larger surface, has garnered much attention due to its massive potential for sustainability due to a process called desorption, during which pollutants are triggered to detach from adsorbent surfaces. Carbon nanotubes (CNTs) are pure carbon nanomaterials that function as ad/desorbents, but encounter issues hindering adsorption efficiency, such as insolubility and aggregation. DNA-wrapped CNTs (DNA-CNTs), however, are soluble and do not aggregate as much, thus they were tested in this study as viable ad/desorbents of Ni(II) metal in water. Upon conducting a batch adsorption experiment incorporating a DNA-CNT dosage over time, which produced effective adsorption, desorption using DNA-CNTs was accomplished through sonication/ultrasound treatment and heat application. It was found that heat application was an effective method for triggering desorption of Ni(II) ions from DNA-CNT surfaces, supporting the hypothesis, but ultrasound treatment instead enhanced adsorption. Significantly improving adsorption efficiency, ultrasound treatment provides a new perspective on adsorption's scalability. Moreover, heat application presents a viable method to desorb pollutants from DNA-CNT surfaces, permitting filtration and subsequent reuse of the same DNA-CNTs for iterative rounds of ad/desorption. Optimized and scaled, this approach has the potential to treat large bodies of metal-contaminated water to provide safe drinking water to millions globally.

Next-Generation Interplanetary Rovers: Physical Implementation & Validation of Neuromorphic Artificial Intelligence Systems for Autonomous & Adaptive Terrain Exploration

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Mentor: Thomas Brown, CREC Academy of Aerospace and Engineering

Space exploration is humanity's next frontier for civilizational expansion. Despite significant technological progress, there is a need for compact and fully autonomous robotic systems for independently exploring unpredictable, extraterrestrial environments to maximize planetary coverage. Neuromorphic artificial intelligence offers advantages in low-latency processing and increased computational density. However, its performance is rarely empirically validated through physical rover integration and testing in Mars-analog conditions, according to literature (November 2025). This research investigates whether embedded neuromorphic controllers, using spiking neural networks (SNNs), combined with a fully modular rover design, improves physical stability and adaptive response to terrain disturbances compared to artificial NN-based control. A modular rover platform, inspired by NASA's CADRE (Cooperative Autonomous Distributed Robotic Exploration) design, was mechanically assembled using primarily 3D-printed components to enable repeatable assembly and ease of maintenance. A Raspberry Pi processed real-time inertial measurement unit (IMU) data from an IMU sensor mounted at the rover's center of mass, while SNN-PPO (spiking neural network-proximal policy optimization) and ANN-PPO (artificial neural network-proximal policy optimization) controllers sent corrective stabilization actions in response to tilts, rocking, and vibration-induced disturbances during traversal. Results demonstrated that SNN-PPO maintained low dynamic tilt deviations ($\sim 1.0^\circ$ mean max) with rapid recovery (6–22 timesteps) and achieved a 100% success rate under a baseline-normalized stability criterion, whereas ANN-PPO exhibited larger deviations (26–98°), delayed stabilization (4,000–15,000 timesteps), and a 20% success rate. The low inter-trial variability further reinforces the modular rover design and enhances mission viability, supporting improved adaptability and durability for long-duration missions. By demonstrating significant adaptivity and autonomy in high-fidelity terrain exploration, this work advances the development of universal interplanetary rovers for future extraterrestrial NASA missions.

Investigating the Effect of Podocyte-Specific Lrp1 Expression on Kidney Function and Podocyte Integrity

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Low-density lipoprotein receptor-related protein-1 (Lrp1) is a multifunctional cell receptor involved in lipid metabolism, endocytosis, immune regulation, and cell cycle control. In the kidney, Lrp1 is ubiquitously expressed, including in podocytes, specialized cells that preserve the glomerular filtration barrier and prevent abnormal urinary protein loss. Podocyte injury is a major cause of glomerular disease, accounting for 75% of kidney failure in the U.S., but the role of Lrp1 in podocytes remains

unclear. Lrp1 was specifically selected as the protein target because it is highly enriched for proteins involved in endocytosis and cargo trafficking, including pathways associated with epidermal growth factor signaling and other essential cellular processes critical for podocyte function. This project will determine the role of podocyte Lrp1 in maintaining the glomerular filtration barrier and kidney function. If Lrp1 is lost in podocytes, then the filtration barrier integrity is disrupted, resulting in proteinuria, because Lrp1 is indispensable for essential cellular processes. The independent variable is podocyte-specific expression of Lrp1, while dependent variables are podocyte function and kidney filtration integrity, measured by proteinuria and morphology. Constants include standardized laboratory conditions, with wild-type littermate mice as controls. Male and female mice will be used at 4-54 weeks of age. Podocyte-specific Lrp1 knockout mice and wild-type littermates will be used. The mentor will provide animals, perform animal work, and collect urine and kidney tissues. Genotyping will confirm podocyte-specific Lrp1 loss by immunofluorescence and evaluate podocyte morphology in vivo and in vitro. Urinary protein will be measured by enzyme-linked immunosorbent assay (ELISA), kidney morphometry assessed by transition electron microscopy, and data statistically analyzed under mentor supervision. Kidney morphometry and urine protein will be quantified using ImageJ and ELISA, and represented using GraphPad Prism. Comparisons between Lrp1-deficient and control mice will determine whether results support the hypothesis. This project is significant because it clarifies the role of Lrp1 in the maintenance of the kidney filtration barrier.

Repurposing Idiopathic Pulmonary Fibrosis Drugs to Treat Vascular Alzheimer's Dementia: A Safe, Effective, and Accessible Approach to Alzheimer's Treatment

Leon Wang

King School, Stamford

Mentors: Braxton Schuldt, MD-PhD candidate, and Joel Blanchard, PhD, Icahn School of Medicine at Mount Sinai

Alzheimer's disease (AD) is a debilitating form of dementia that affects 55 million patients worldwide. Found in one in four people, the most common genetic risk factor for AD is the APOE4 gene, with homozygous carriers of the APOE4 gene being up to 12 times as likely to develop AD as their APOE3 counterparts. APOE4 is closely linked to cerebral amyloid angiopathy (CAA)—the deposition of beta-amyloid on blood vessels—and blood-brain barrier (BBB) dysregulation, ultimately resulting in devastating cognitive deficits. Thus, the goal of this study was to elucidate the pathology behind APOE4-induced BBB dysregulation and CAA, as well as to identify potential treatments. We hypothesized that TGF β signalling and the adhesive properties of fibronectin in the extracellular matrix contribute to BBB neuroinflammation and vascular amyloid deposition. To that end, we used 3D co-cultures of induced pluripotent stem cells (iPSC)-derived endothelial and pericyte cells and found that the presence of fibronectin significantly increases vascular amyloid binding. Excitingly, we identified Pirfenidone and Nintedanib—currently approved for idiopathic pulmonary fibrosis—reduced biomarkers of BBB dysregulation, marking a promising finding for future treatments. Our findings suggest the promising nature of fibronectin and TGF β and work towards developing a treatment for millions of patients affected by vascular Alzheimer's dementia worldwide.

Design of a Novel, Dual-Functioning, T-Cell-Engaging, and Cytarabine-Based Nanotherapeutic for Acute Myeloid Leukemia Treatment

Lula Wang

Greenwich High School

Mentor: Andrew Bramante, Greenwich High School

Leukemia remains a leading cause of global cancer mortality, with acute myeloid leukemia (AML) presenting the most aggressive clinical profile, with frequent relapse even after treatment. Over 40% of chemotherapy patients suffer from toxic side effects due to nonspecific targeting, highlighting the urgent need for improved therapeutic systems. Herein, a dual-functioning nanocarrier (NC) system, termed ARACIL-C3, was engineered to achieve 94% cell mortality via precise chemoimmunotherapy. This system uses anti-CD3 and anti-CD33 antibodies to create an artificial synapse that bridges T-cells and AML cells. Then, pH-triggered dissolution releases IL-12 to enhance T-cell cytotoxicity and prevent recurrence, followed by a targeted cytarabine (Ara-C) chemotherapy payload. Synthesis was confirmed via scanning electron microscopy (SEM), dynamic light scattering (DLS), and attenuated total reflectance-Fourier transform infrared (ATR-FTIR) spectroscopy analyses. To evaluate the system's "bridge-forming" capability, fluorescence microscopy confirmed that ARACIL-C3 NCs successfully tethered T-cell models to Kasumi-1 AML cells. ARACIL-C3 dissolution studies in normal extracellular fluid versus AML tumor-microenvironment (TME) then showed 100% degradation of the poly(lactic-co-glycolic acid) (PLGA) layer within five-minutes, releasing IL-12 to strengthen T-cells. High-performance liquid chromatography (HPLC) analysis was subsequently used to demonstrate ARACIL-C3 release, with 96% of a 9.7 μ g Ara-C load released upon introduction to a simulated AML-TME. Finally, therapeutic impact was evaluated in vitro using Kasumi-1 AML cells. While treatment with free-Ara-C resulted in 36% cell mortality, ARACIL-C3 NCs achieved 94% cell death. Fluorescence imaging corroborated these results, showing initial NC attachment followed by cellular apoptosis over 24 hours. These findings highlight a lower-toxicity alternative to conventional chemotherapy, showing increased cytotoxicity and selectivity in Kasumi-1 cells to support this project's creation of a life-saving nanotherapeutic.

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February 28, 2026

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