

Sixty-Second Connecticut

JUNIOR SCIENCE and HUMANITIES SYMPOSIUM

at UConn Health, Farmington, Connecticut
February 22, 2025



**UCONN
HEALTH**

**THE NATIONAL SCIENCE TEACHING ASSOCIATION
under contract with
THE U.S. OFFICE OF THE SECRETARY OF DEFENSE,
THE U.S. DEPARTMENTS OF THE ARMY, NAVY, AND AIR FORCE and
UConn Health/CT Area Health Education Center**



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.

A part of

THE U.S. OFFICE OF THE SECRETARY OF DEFENSE and U.S. DEPARTMENTS OF THE ARMY/NAVY/AIR FORCE JUNIOR SCIENCE AND HUMANITIES SYMPOSIA PROGRAM

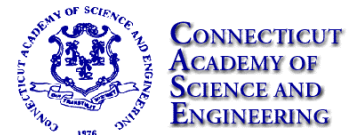
with support from

UConn Health/CT Area Health Education Center
(AHEC)



and

CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING



Program Summary

	Saturday, February 15	Judging of Oral and Competitive Poster Presenters		
	Online February 17–21	Pre-week Events		
	Asynchronous timing	View and comment on STEM Poster Exhibition (alumni-mentored); view Competitive Posters and recordings of Oral Presentations.		
	Asynchronous timing	View lab tour videos and alumni spotlights online.		
	Saturday, February 22	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)/ Chaperone Workshop (non-students) 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)/ Chaperone Workshop (non-students) 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)/ Chaperone Workshop (non-students) Group A	3 rd Competitive Poster Session Group B
	12:30 – 12:50 PM	Awards and closing remarks—everyone attends. <i>Winners and runner-up to represent Connecticut as the National Delegation will stay after 12:50 to learn details.</i>		
	12:50 – 1:00 PM	Grab a boxed lunch and depart.		

Sixty-Second Connecticut JUNIOR SCIENCE and HUMANITIES SYMPOSIUM at UConn Health

SATURDAY, FEBRUARY 22, 2025

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, UConn Health
Executive Vice President for Health Affairs
Recorded welcome: <https://tinyurl.com/3hcefr63>



Welcome

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



Briefing

Brittany Knight, PhD
Regional Co-Director, CT-JSHS
Director of Operations, United States
Association for the Study of Pain



Keynote Address **Alix Deymier, PhD**
Associate Professor of Biomedical Engineering,
UConn School of Dental Medicine
“The Amazing Adventures of Alix Deymier:
Finding Passion in the Skeleton and Beyond”

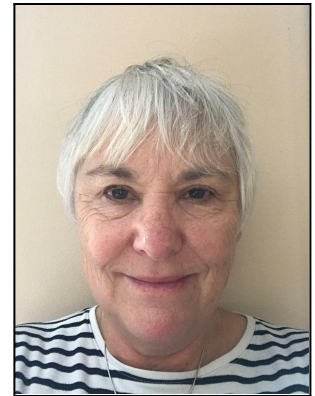


BREAK/TRANSITION

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

2025 HUMANITIES ACTIVITY:
Ethics of Private Space Exploration
Developed by Heather Biancheri, MS
Brookfield High School

2025 CHAPERONE WORKSHOP:
A STEM Research Program at Your School:
Moving from “Mission Impossible”
to “Mission Accomplished”
Led by Megan Rader, MEd
Eastern Connecticut State University
Early STEM Research Program
(dual credit high school/college course)
Manchester High School (retired)



BLOCK #1

9:45 – 10:30 a.m.

Activity/ Location	Group A: 1st Oral Session (Names are below.) Keller Auditorium	Group B: Humanities Activity (students) Massey Auditorium Chaperone Workshop Patterson Hall	Group C: 1st Competitive Poster Session (Names are below.) Low Learning Center
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First Oral Session Presenters**Vedant Kansara**

Farmington High School

Mentor: Frederick Varn, PhD

*Investigating Age-Related Myeloid Cell States in Glioblastoma***Ethan Joseph**

Engineering and Science University Magnet School

Mentor: Paula Matei-Grysiak

*Implementation and Validation of a Novel Machine-Learning–Based Mobile Mechanocardiography System for Arrhythmia Detection***Harshil Yerrabelli**

Conard High School

Mentor: Dr. Bonnie Mayer

*Hybrid Quantum-Classical Circuit Design: Optimizing Computational Efficiency through Integrated Reversible Logic and Hardware-Aware Quantum Processing***Jingyan (Sabrina) Liu**

Choate Rosemary Hall

Mentor: Shiyao Gu

*A Novel Mantis-Shrimp–Based Smart Glove for Stroke Rehabilitation***Maria Kholmanskikh**

Darien High School

Mentor: Margaret Elizabeth Ross, MD, PhD

*PLA as a Novel Method for Assessing Rho GTPase Activity***Rithvik Suren**

CREC Academy of Aerospace and Engineering

Mentor: Thomas Brown

Developing Autonomous and Adaptive Systems for Space-Exploration Robotics with Neuromorphic Frameworks and Artificial Intelligence

First Competitive Poster Session Presenters

Bruno Reinhoefer Ribeiro

King School

Mentor: Dr. Simon Vecchioni

An Effective Water Treatment Method: Adsorption of Nickel(II) Ions in Water Using DNA-Wrapped Carbon Nanotubes

Lucia Vivanco

King School

Mentor: Dr. Victoria Schulman

Mitigating Heat Stress in Saccharina latissima and Gracilaria mammillaris: The Role of Nutrient Additives in Enhancing Resilience to Climate Change

Nolan Francis

Staples High School

Mentor: Amy Parent

Effects of Vitamin D Supplementation on Muscle Function in C. elegans with a Mutation in the Dystrophin Gene

Sowa Laryea-Adjei

King School

Mentor: Dr. Victoria Schulman

Making a Real-Time Water Quality Monitor: An Arduino-Based System for Measuring Water Contamination

Victoria Makarov

Laurel Springs School (online)

Mentor: Vera Ulanovskaya

Research on Autoimmune Disease Spectrometer (RAD-Spec): A Machine-Learning-Based Application for Improving Accessibility to Research on Autoimmunity

Yobin Kim

The Hotchkiss School

Mentor: Woo Rin Lee, PhD

Uncovering Metastasis Gene Expression Signatures and Unique Traits in Migrating Cancer Cells Using mRNA Sequencing and Transwell Assays

BREAK/TRANSITION

10:30 – 10:40 a.m. Refreshments

BLOCK #2

10:40 a.m. – 11:25 a.m.

Activity/ Location	Group B: 2nd Oral Session (Names are below.) Keller Auditorium	Group C: Humanities Activity (students) Massey Auditorium Chaperone Workshop Patterson Hall	Group A: 2nd Competitive Poster Session (Names are below.) Low Learning Center
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Second Oral Session Presenters**Cooper Taylor**

Greenwich Country Day School

Mentor: Dr. David Handelman

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

Greenwich High School

Mentor: Andrew Bramante

*Lipid-Based Codelivery of Doxorubicin and siRNA PD-L1, as a Multifunction Chemoimmunotherapy, Selective to PDAC via Its MUC1 Overexpression***Marley Wies**

Greenwich High School

Mentor: Andrew Bramante

*Extraction of Cellulose Nanocrystals via Sulfuric Acid Hydrolysis from Post-Consumer Cotton-Elastane Textile Blends with Elastane Recovery***Samarth Basanth**

South Windsor High School

Mentor: Suma Basavarappa

SiExo: A Novel AI-Optimized siRNA-Loaded Exosome Platform for Targeted Gene Therapy in CNS Disorders

Second Competitive Poster Session Presenters

Adeline Thompson

Greens Farms Academy

Mentor: Dr. Mathieu Freeman

Equine and Human Heart Rate Variability Synchronization as a Model for Potential Atrial Fibrillation Treatment

Andrew Hsu

Fairfield College Preparatory School

Mentor: Dr. Panayiotis Meleties

Can Long Gaming Sessions Be a Method to Boost Mood?

Brian Weiss

Joel Barlow High School

Mentor: Paul Testa

Evaluating Market Efficiency through Deep Learning: A Performative Analysis of LSTM Neural Networks, Actor-Critic Reinforcement Learning Models, and Technical Indicators

Lourdes Isabella Hassan

Greens Farms Academy

Mentor: Dr. Mathieu Freeman

Studying Theories of Prebiotic Chemical Evolution and Abiogenesis by Testing the Presence of the Precursors of Life in Clay Research

Nivritth Ananth Iyer

Engineering and Science University Magnet School

Mentor: Ali Senejani, PhD

Evaluating LYVE1 Gene Expression in Breast Cancer Using qPCR Analysis and Comparing with Hyperparameter-Tuned Models for LYVE1 Gene Expression in Pancreatic Cancer

Palaniappan Manikandan

CREC Academy of Aerospace and Engineering

Mentor: Dr. Michelle Bellinger

Using Piezoelectric Sensors to Harvest Energy from Automobile Tires and Road Surface

Tyra Stephenson

Greens Farms Academy

Mentor: Dr. Juli Gerdes

Examining the Cognitive Impact of Lower Inhalation Levels of Chlorine Gas on Drosophila melanogaster

BREAK/TRANSITION

11:25 – 11:35 a.m. Refreshments

BLOCK #3

11:35 a.m. – 12:20 p.m.

Activity/ Location	Group C: 3rd Oral Session (Names are below.) Keller Auditorium	Group A: Humanities Activity (students) Massey Auditorium Chaperone Workshop Patterson Hall	Group B: 3rd Competitive Poster Session (Names are below.) Low Learning Center
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Third Oral Session Presenters**Dillon Maltese**

King School

Mentor: Dr. Victoria Schulman

*Voice-Controlled Robotic Arm for Assisting Complex Surgical Tasks***Kashvi Parashar**

New Canaan High School

Mentor: Dr. Mukul Bansal

*Improving the Biological Accuracy of Gene Tree Simulations: Comparing Rates of Duplication, Transfer, and Loss in Real and Simulated Gene Trees with RANGER-DTL***Shriya Natarajan**

Wilton High School

Mentor: Nataraj Dasgupta

*A Novel Rubric-Driven Approach to Predict Invasive Species Spread in the Northeast Using DBSCAN on iNaturalist Data***Vito Scutari**

King School

Mentor: Jordan Tewell, PhD

*Comprehensive Assessment for Executive Dysfunction***William Boberski**

Staples High School

Mentor: Amy Parent

The Effect of Diet Composition on Lifespan and Colorectal Cancer Progression in the Drosophila Midgut

Third Competitive Poster Session Presenters

Henry Jin

Greenwich High School

Mentor: Andrew Bramante

Development of a Novel Deep Reinforcement Learning Algorithm for Autonomous Drone Control

Matthew Park

Amity Regional High School

Mentor: Feng Qian, PhD

Comparative Analysis of Virulence and Antibiotic Resistance Genes in Stimulated vs. Unstimulated Saliva to Assess Observed Oral Disease Risk

Nicholas Lu

Amity Regional High School

Mentor: Dr. Corey S. O'Hern

Modeling Breast Cancer Cell Invasion Using Active Brownian Dynamics

Salma Maklad

Amity Regional High School

Mentor: Dr. Jaan Aru

Analyzing the Relationship between Priming and People's Accuracy, Confidence, and Speed in Insight Problem-Solving

Tyler Malkin

Greenwich High School

Mentor: Andrew Bramante

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

BREAK/TRANSITION

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

AWARDS CEREMONY AND CLOSING REMARKS

12:30 – 12:50 p.m.

Keller Auditorium

Evaluation

Submit completed form and receive a raffle ticket

Acknowledgments

Brittany Knight, PhD
Regional Co-Director, CT-JSHS

Awards

- Poster Presenters
- Backyard Scientist Awards
- STEM Poster Exhibition:
People's Choice Award
- Oral Presenters
- CT Delegation to the 63rd National JSHS
- UConn Academic Excellence Scholarship
- Teacher Award

Barnes & Noble Gift Cards and Merchandise

- People's Choice Award Voters
- Exhibit Quest
- Evaluation Raffle

Winners and runner-up to represent Connecticut as the National Delegation will stay after 12:50 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

Aroush Amir, Amity Regional High School

Determining the Rate of Cell Death in Tumor Initiation in Colon Cancer

Bryanna Boroze and Jayden Lin, Connecticut International Baccalaureate Academy

Using Time Lapse Imaging to Uncover the Role of LSD1 during Erythroid Fate Specification

Maham Chaudhary, Sport and Medical Sciences Academy

Repair and Regeneration of Ischemic Skin Flap by Thioredoxin-1 Overexpression

Viola Cullen, Greens Farms Academy

Drosophila melanogaster as a Potential Model for Host-Microbe Interactions in IBD: Comparing the Efficacy of Different Probiotic Species on Dextran Sodium Sulfate-Induced Colitis in Drosophila melanogaster

Sophia Dalrymple, Sacred Heart Academy

Talc vs. No Talc

Hannah Dacruz, Greenwich High School

Targeted Delivery of Melittin Anti-inflammatory Peptides via a Eudragit-Coated Sporopollenin Exine Capsule for Effective Treatment of Crohn's Disease

Lino Delgado-Scott, Wilby High School

Environmental Transportation Effects and Solutions

Bailey Downey, Manchester High School

Measuring the Effect of Nitrogen Enrichment on the Stimulation of Temperate Coral, Astrangia poculata, from Quiescence

Elizabeth Gomez, Manchester High School

The Growth of Prevotella melaninogenica in Different Alimentative Solutions

Anas A. Hales, Manchester High School

Determining the Effect of 3D-Printed Staghorn, Table, and Mushroom Coral on Flood Wave Breaking and Its Potential Use Providing Coastal Relief

Remona Hales, CREC Academy of Aerospace and Engineering

Quagga Mussels' Potential Benefits in Water Filtration while in Controlled Environments

Anousha Hashim, Berlin High School

The Role of DLL1, SMYD1, VHL, and CALR in Osteosarcoma Tumorigenesis

Oscar Hecker, Greens Farms Academy

Sports Nutrition—Approaches amongst U.S. Junior Squash Athletes

Mia Hernandez, Manchester High School

The Biodegradation of UV-Treated Polyethylene Terephthalate and Polypropylene by Aspergillus terreus

Aalif Hoque, Bethel High School

Using Computational Simulations of Antibodies to Target the Streptococcus anginosus Surface Protein TMPC to Mitigate Gastric Cancer

Emma Imanov, Amity Regional High School

Testing Clover Density to Reduce Pesticide Uptake in Spinach Food Crops, Improving Food Safety to Meet FDA Levels

Meera Kannan, South Windsor High School and **Gabrielle Bridgewater**, Tolland High School
Leveraging Public AI Tools to Explore Systems Biology Resources

Lily Keehlwetter, Darien High School
Association between Food Insecurity and Mortality Outcomes among Cancer Survivors in the U.S.

Eric Kim, Avon High School
The Absence of Aminoacyl-tRNA Deacylases Modulates Antibiotic Resistance

Calvin LaFrance, The Williams School
How to Measure a Pianist's Touch

Brooke Lincoln and Shees Siddiqy, Connecticut International Baccalaureate Academy
The Role of Nuclear Transport in the Regulation of Microtubule Detyrosination

Jackson McBean, Greens Farms Academy
A Pilot Study of the Impact of Weekly Soccer-Specific Training Hours on Field Test Performance

Emily Morton, Thomaston High School
Fucus vesiculosus Extract as a Biostimulant for Radish Plant Growth

Vishnu Mukku, Avon High School
Pathonix: Enhancing Histopathological Ovarian Cancer Detection with an Explainable and Efficient Ensemble Learning Framework

Mahnoor Nomani, King School
Beta-Blockers Effectively Decrease Insulin-Induced Tachycardia: Potential Combination Therapy for Diabetics with Cardiovascular Disease

Sophie Noujaim, Amity Regional High School
Effects of Use of an Electronic Device on Immediate Reaction Time

Aakarsh Patel, Ridgefield High School
Projections of Critical Global Warming Thresholds in Connecticut Using Data Analytics

Marko Paxi, East Catholic High School
Testing the Cytotoxicity of Bioactive Lipids Using Dorsal Root Ganglion Derived Cell Line

Katerin Pineda, Greens Farms Academy
Investigating miR-30a Modulation and Its Impact on Glucose Uptake in 3T3-L1 Cells for Metabolic Disorder Research

Sahasra Reddy, Loomis Chaffee School
RNA-Based Aptamers Targeting Claudin-5 Protein in Blood as a Biomarker for Suicidal Behavior

Cooper Roth, King School
Force Needed from an Object to Fly at a Relative Speed

Lydia San Jose, Greens Farms Academy
Effects of Exosomes Secreted by Bone-Marrow Mesenchymal Stem Cells and Hydroxyapatite/Collagen Paste on the Acceleration and Promotion of Tendon-Bone Tunnel Healing in an ACL Reconstruction

Aditi Sidhartha, Amity Regional High School
Development of a Split Luciferase Complementation Assay to Better Quantify the Interaction between Tat and CyclinT1.

Ann Slocum, Sacred Heart Greenwich

The Effects of Age, Gender, and Costoclavical Symmetry or Asymmetry on the Costoclavical Interval for Neurogenic Thoracic Outlet Syndrome (nTOS) Patients

Joseph Vatner, Amity Regional High School

Computation Investigation of the Genetic Risk of Bipolar Disorder

Roopshi Vohra, Ridgefield High School

How Nutritive Versus Non-nutritive Sweeteners Affect Sleep Quantity in Drosophila melanogaster

Molly Womer, Amity Regional High School

Examining Hudson River Plankton Community Composition via Environmental DNA Analysis to Gather Baseline Data for Future Environmental Health Monitoring

Elijah Yurkovsky, Ridgefield High School

The Effects of Water Consumption on Polystyrene Consumption in Tenebrio molitor

Scarlett Zhai, Amity Regional High School

Determining the Effect of the Protein SAMP-1 on Chromosome Segregation in C. elegans Embryos

The STEM Poster Exhibition will be online at <https://tinyurl.com/3paq5333>, password “STEM2025”, through February 22, 2025.



2025 Registered High Schools/Programs

Academy of International Studies, Bloomfield	Joel Barlow High School, Redding
Academy of Science and Innovation, New Britain	Killingly High School
ACES at Chase, Waterbury	King School, Stamford
Achievement First Hartford High School	Laurel Springs School (online), Ojai, CA
Amity Regional High School, Woodbridge	Loomis Chaffee School, Windsor
Avon High School	Madina Academy, Windsor
Berlin High School	Manchester High School
Bethel High School	New Canaan High School
Choate Rosemary Hall, Wallingford	Norwich Technical High School
Classical Magnet School, Hartford	Plainville High School
Conard High School, West Hartford	Ridgefield High School
Connecticut International Baccalaureate Academy, East Hartford	Sacred Heart Academy, Hamden
CREC Academy of Aerospace and Engineering, Windsor	Sacred Heart Greenwich
Daniel Hand High School, Madison	Simsbury High School
Darien High School	South Windsor High School
East Catholic High School, Manchester	Southington High School
East Granby High School	Sport and Medical Sciences Academy, Hartford
East Hartford High School	Staples High School, Westport
Engineering and Science University Magnet School, West Haven	Thomaston High School
Fairfield College Preparatory School	Tolland High School
Farmington High School	UConn Health Disparities Institute
Glastonbury High School	UConn Health's Health Career Opportunity Programs (HCOP)
Global Experience Magnet School, Bloomfield	UConn's Connecticut Collegiate Awareness and Preparation (ConnCAP) Upward Bound Math-Science
Greens Farms Academy, Westport	University High School of Science and Engineering, Hartford
Greenwich Country Day School	Watertown High School
Greenwich High School	Wilby High School, Waterbury
Hall High School, West Hartford	The Williams School, New London
Hartford Promise	Wilton High School
Hopkins School, New Haven	Windham High School, Willimantic
The Hotchkiss School, Lakeville	

SPONSORS

- Connecticut Academy of Science and Engineering
- Connecticut Science Supervisors Association
- Connecticut Science Teachers Association
- The National Science Teaching Association under contract with the U.S. Office of the Secretary of Defense; the U.S. Departments of the Army, Navy, and Air Force
- UConn Health/CT Area Health Education Center (AHEC)
- UConn Office of Undergraduate Admissions

DONOR (raffle prizes)

- Barnes & Noble at UConn Health, Farmington

COOPERATING ORGANIZATIONS

- AmeriCorps HealthForward Program (CT AHEC Network)
- Connecticut Science and Engineering Fair
- UConn College of Liberal Arts and Sciences
- UConn Department of Natural Resources
- UConn Graduate School of Biomedical Science
- UConn School of Dental Medicine
- UConn School of Engineering
- UConn School of Medicine

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

- Petra Clark-Dufner, MA, Program Director CT-JSHS, 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, Regional Co-Director CT-JSHS, 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
- Robert Pijewski, PhD, Anna Maria College, Paxton, Mass.
- Victoria Schulman, PhD, Regional Co-Director CT-JSHS, King School, Stamford
- Ralph Yulo, PhD, Eastern Connecticut State University, Willimantic

ADMINISTRATIVE TEAM

- Joanna Moon, CT AHEC *HEALTHForward* AmeriCorps member
- Ellen Ravens-Seger, CT AHEC Administrative Program Coordinator
- Cathy Torrisi, CT-JSHS Communications

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

ABSTRACTS

Oral Presenters

SiExo: A Novel AI-Optimized siRNA-Loaded Exosome Platform for Targeted Gene Therapy in CNS Disorders

Samarth Basanth

South Windsor High School

Mentor: Suma Basavarappa (parent/guardian)

Central nervous system (CNS) disorders, such as Huntington's, Alzheimer's, and Parkinson's diseases, affect over 50 million people worldwide, posing immense clinical and societal challenges. A major hurdle in treating these disorders is the blood-brain barrier (BBB), which restricts over 98% of therapeutic agents from reaching the brain. This study presents **SiExo**, an AI-driven platform designed to optimize siRNA-loaded exosomes for targeted CNS gene therapy. By integrating convolutional neural networks (CNNs) and reinforcement learning, SiExo refines exosome properties, including lipid composition, ligand density, and siRNA encapsulation efficiency, to enhance BBB penetration and neuron-specific delivery.

The platform employs molecular dynamics simulations to ensure siRNA stability and interaction accuracy, achieving a binding free energy of -25 kcal/mol. Utilizing transferrin and rabies virus glycoprotein (RVG) ligands, SiExo increases BBB permeability by 3.5-fold and siRNA loading efficiency by 2.8-fold compared to traditional methods. In Huntington's disease models, it demonstrated a 62% reduction in mutant HTT mRNA expression, highlighting its efficacy.

SiExo's scalable and adaptable design supports applications across diverse CNS disorders, including Alzheimer's and Parkinson's diseases, offering a breakthrough in precision-targeted therapies. Future work will include in vivo validation and clinical translation, focusing on scalability and therapeutic impact in neurodegenerative and neuroinflammatory diseases. This research exemplifies the potential of AI to revolutionize CNS drug delivery, overcoming critical barriers and improving patient outcomes.

The Effect of Diet Composition on Lifespan and Colorectal Cancer Progression in the Drosophila Midgut

William Boberski

Staples High School, Westport

Mentor: Amy Parent, Staples High School

Colorectal cancer (CRC) is the third most frequently diagnosed cancer, and the incidence of early-onset CRC (EOCRC) in patients under 50 is rising (Sung et al., 2021) (O'Reilly et al., 2023). These trends in EOCRC are not fully understood, and may be related to diet (O'Reilly et al., 2023). A transgenic Apc1/Apc2-Ras^{v12} *Drosophila melanogaster* model (gifted from Dr. Andreu Casali) was used to compare the impact of standard, high-fat, and high-fiber diets on progression (Martorell et al., 2014) (Bangi et al., 2016). Experimental diets were prepared from the Bloomington standard cornmeal medium, supplemented with $\pm 10\%$ coconut oil for high-fat or $\pm 10\%$ psyllium husk for high-fiber (Liao et al., 2020) (Lambeau et al., 2017). Tumor progression was indirectly measured by lifespan, and every other week by fecal depositions and fluorescence microscopy of GFP-labeled tumor clone cells in the midgut. It was anticipated that high-fat diets would be associated with a shorter lifespan, fewer fecal depositions, and more tumors compared to high-fiber diets (Cheng et al., 2020) (Martorell et al., 2014). Preliminary data suggests that flies on high-fat diets may have shorter lifespans and more fecal depositions. By comparison, flies on high-fiber diets may have fewer tumors; for example, a high-fat midgut sample had approximately 18 tumors, while a high-fiber sample had approximately 4 (n=1 for each). This preliminary data is promising and supports additional study, in order to elucidate causes for rising EOCRC rates, and contribute evidence related to dietary intervention in CRC patients.

Implementation and Validation of a Novel Machine-Learning-Based Mobile Mechanocardiography System for Arrhythmia Detection

Ethan Joseph

Engineering and Science University Magnet School, West Haven

Mentor: Paula Matei-Grysiak, Engineering and Science University Magnet School

Irregularities in heart rhythm patterns, known as arrhythmias, may reveal various cardiac diseases. Currently, electrocardiograms (ECGs) are predominantly used to record heart rhythm, and abnormalities in these measurements can be indicative of underlying

cardiac pathology. ECGs record electrical potential differences induced by the contraction of heart muscle fibers; however, they require time-consuming surface/electrode preparation and complex, multi-channel signal processing. The prevalence of inexpensive mobile devices containing integrated, high-precision accelerometers and gyroscopic sensors has presented cardio-mechanical monitoring techniques such as seismocardiography (SCG) and gyrocardiography (GCG), which record mechanical vibrations and movements associated with heart activity, as potential alternatives to ECGs, with simpler preparation and processing requirements. This research project aims to implement and validate a machine-learning– based smartphone application for arrhythmia detection through gyroscope and accelerometer readings taken from a smartphone resting on the sternum. Two open-access datasets containing gyroscope and accelerometer readings taken from subjects with and without valvular heart diseases were obtained and statistically processed for use in machine-learning training. Subsequently, a deep convolutional neural network (CNN) was developed and trained upon the processed dataset for the purpose of identifying arrhythmia in cardio-mechanical recordings. A statistically significant relationship between the training dataset and binary classifiers (healthy/arrhythmic) was hypothesized to yield a viable machine-learning model. Ultimately, evaluation of the trained model resulted in a satisfactory classification accuracy above 90%. The validated deep convolutional neural network was incorporated into a cross-platform mobile application for Android and iOS devices, providing an intuitive interface for future clinical testing.

Investigating Age-Related Myeloid Cell States in Glioblastoma

Vedant Kansara

Farmington High School

Mentor: Frederick Varn, PhD, The Jackson Laboratories

Glioblastoma (GBM) is the most common malignant brain cancer in adults, with an average survival time of around 15 months, and is especially aggressive in older patients, despite standard of care treatment including surgery, radiation, and chemotherapy. In the brain, myeloid cells help maintain homeostasis and resolve damage from diseases like cancer. Studies in mice showed changes in gene expression profiles and their relative proportions in microglia during the process of healthy aging. Single-nucleus RNA sequencing data from mice intracranially injected with GL261 murine tumor cells—one aged (2 years) and one young (3 months)—was used in this project. Differential expression analysis and reference mapping were used to classify cells with high confidence, and sub-clustering revealed myeloid subtypes including microglia and macrophages. Microglial states were leveraged from past mouse studies, and the relative proportions of these states were compared across young and old samples to determine potential age-related changes. In the GBM environment, interferon-related and activated genes (*H2-Ab1*, *H2-Aa*, *Cd74*) were enriched in older microglia, and the activated cell states' proportions increased with age, suggesting that microglia become more activated and have increased immune activity/responsiveness with age. These changes in microglial signatures may explain increased neuro-inflammation and degeneration with age, which make the older brain more vulnerable to cancer and less resistant to the body's immune response. Leveraging these age-related microglial state changes to human studies can provide valuable insight into targetable genetic pathways to slow GBM progression and potentially prolong survival in older patients through novel brain cancer treatments.

PLA as a Novel Method for Assessing Rho GTPase Activity

Maria Kholmanskikh

Darien High School

Mentor: Margaret Elizabeth Ross, MD, PhD, Weill Cornell Medicine

Small Rho GTPases are proteins that act as molecular on/off switches. Extracellular signals or intrinsic cellular programs promote GTP loading of Rho GTPases, activating them. In this state, they bind to and activate downstream effector molecules. When Rho GTPases hydrolyze GTP to GDP, they become inactive and cannot transduce signals. Rho GTPases regulate essential processes like cell division, motility, shape, and phagocytosis, primarily targeting the cytoskeleton. Dysregulation of Rho GTPases is linked to diseases such as immune disorders, cardiovascular diseases, neurodegeneration, and cancer. Accurate assessment of Rho GTPase activity is crucial for understanding biological processes and disease pathophysiology, and for developing therapeutics.

Current methods to evaluate Rho GTPase activity include pull-down assay, bio complementation (BCA), and fluorescence resonance energy transfer (FRET) assay. Pull-down assays measure endogenous Rho GTPases, but lack cellular resolution and are semi-quantitative. BCA and FRET measure activity in individual cells quantitatively, but rely on exogenous sensor molecules. All three methods cannot monitor Rho-GTP interaction with specific effectors, despite evidence that only a fraction are activated at any time.

We devised a novel method to monitor Rho GTPase activity using proximity ligation assay (PLA). PLA combines the advantages of pull-down assays (measuring endogenous molecules) with those of FRET and BCA (subcellular resolution and quantification). PLA also enables monitoring Rho-GTP interaction with specific binding partners. We optimized fixation conditions for anti-RhoA and anti-RhoC antibodies, showing specificity using shRNA. We observed a significant increase in PLA signal under conditions promoting Rho-GTP interaction with ROCK1, validating PLA's utility in monitoring Rho GTPase activity.

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

Jingyan (Sabrina) Liu

Choate Rosemary Hall, Wallingford

Mentor: Shiyao Gu, Youth Computational Science Development Center

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 usable 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.

Voice-Controlled Robotic Arm for Assisting Complex Surgical Tasks

Dillon Maltese

King School, Stamford

Mentor: Dr. Victoria Schulman, King School

In the U.S., 250,000 people die from medical errors yearly, with over 4,000 from surgery-related accidents. Augmented reality (AR) is being integrated into operating rooms to enhance precision, but AR headsets create challenges, particularly in handling tools like ultrasound probes, which are essential for updating the headset. Surgeons, already managing multiple tasks, struggle with precise probe manipulation, increasing the risk of errors. To reduce this risk, I developed a voice-controlled robotic arm that functions as an additional hand, reducing multitasking and improving efficiency. The arm was 3D modeled, 3D printed with hard plastic, and powered by Nema23 stepper motors with two-stage epicyclic gearboxes for precise movement. Motion control and stability tests demonstrated remarkable success, and further development is enhancing claw movements. This robotic system allows for real-time responsiveness to voice commands, enabling seamless integration with AR headsets and reducing manual workload during surgery. The prototype has been well-received by doctors at Weill Cornell Medical Center, who recognize its potential to assist surgeons in maintaining focus and precision. By automating key aspects of ultrasound probe handling and other surgical tasks, this innovation could significantly decrease surgical errors and improve patient outcomes. As research progresses, further refinements will ensure greater stability, control, and adaptability in various surgical scenarios. With the successful development of a fully functional robotic arm, this technology has the potential to revolutionize surgery by optimizing AR headset use and providing surgeons with reliable, precise, and intuitive robotic assistance, ultimately enhancing surgical safety and efficiency.

A Novel Rubric-Driven Approach to Predict Invasive Species Spread in the Northeast Using DBSCAN on iNaturalist Data

Shriya Natarajan

Wilton High School

Mentor: Nataraj Dasgupta, Syneos Health

Invasive species in the Northeast are spreading rapidly, with a 36% increase expected by 2050. Despite 21,313 hours spent on eradication efforts in Connecticut this year, only 60 out of 169 towns have been reached, highlighting the need for a data-driven approach to prioritization. This project hypothesizes that DBSCAN can reliably analyze recent data to identify which invasive

plants are most likely to spread and which to prioritize for management. The rubric was developed from a literature-based invasiveness ranking and iNaturalist observations. A dataset of 15,000+ observations of 20 invasive plant species was compiled, filtered to include observations from January 2020 through October 2024. DBSCAN was applied annually to calculate total cluster areas. The rubric ranked species from 1 to 5 across four factors: observation density (largest clusters across years), potential for spread (greatest increase 2020–2024), ecological impact (literature review), and management urgency (weighted average of the three primary factors). Black Swallow-wort and Lesser Celandine topped the management urgency scores. Compared to relying on literature review, the rubric changed the rankings for the following: Multiflora Rose (-1.44), Common Reed (-1.17), Dame's Rocket (-1.04), Purple Loosestrife (-0.97), Autumn Olive (-0.82). This is due to lower observation density and spread potential scores. However, iNaturalist data may not reflect actual plant populations, as it relies on user submissions and includes only "research grade" images. Future steps include expanding the dataset, extrapolating missing points from prior year observations, and factoring in areas without plant observations.

Improving the Biological Accuracy of Gene Tree Simulations: Comparing Rates of Duplication, Transfer, and Loss in Real and Simulated Gene Trees with RANGER-DTL

Kashvi Parashar

New Canaan High School

Mentor: Dr. Mukul Bansal, University of Connecticut

Understanding gene family evolution is crucial for studying microbial adaptation, antibiotic resistance, and emerging pathogens. Phylogenetic reconciliation, a key computational technique, infers evolutionary events such as gene duplication, loss, and horizontal transfer within gene families. However, discrepancies between simulated and real evolutionary datasets challenge the accuracy of these models. This study evaluates the biological realism of simulated gene trees generated using RANGER-DTL, a phylogenetic reconciliation software developed in Dr. Mukul Bansal's computational biology lab at UConn. The key research objective was to determine whether the simulated event rates align with real event rates. To address this, I developed a Python tool to automate the analysis of thousands of real and simulated gene trees using RANGER-DTL. Comparing the real event rates to the simulated rates revealed discrepancies, leading to refinements in RANGER-DTL's simulation parameters for greater biological accuracy of future simulations. My contributions are being incorporated into an upcoming publication, highlighting the importance of biological accuracy in simulations, software, and research. These improvements enhance the reliability of phylogenetic models used in evolutionary biology, leading to better predictions of gene duplication, transfer, and loss events. More broadly, these improvements guide future research in microbiology, genetics, and computational biology. By ensuring that simulated datasets reflect biological patterns, researchers can better understand gene family evolution and reliably study issues like microbial adaptation, the spread of antibiotic resistance, and pathogen evolution.

Comprehensive Assessment for Executive Dysfunction

Vito Scutari

King School, Stamford

Mentor: Jordan Tewell, PhD, Sacred Heart University

Each year, over one million people in the United States suffer from traumatic brain injury (TBI), with 230,000 requiring hospitalization and 50,000 ultimately dying. Of those hospitalized, 34% are discharged with TBI-related disabilities, contributing to the estimated 5.3 million Americans living with TBI-induced impairments today. These impairments severely impact patients' ability to perform everyday tasks. Additionally, TBIs can affect anyone, from an average person to a professional athlete. Furthermore, traditional assessment methods for executive dysfunction are not only costly and time-consuming, but also prone to human error due to their paper-and-pencil or verbal nature, limiting their effectiveness in frequent evaluations. This project presents the Comprehensive Assessment for Executive Dysfunction (CAED), a mobile, tablet-based, gamified tool designed to overcome these challenges. By integrating gaming elements with clinical evaluation, CAED offers a more accurate, efficient, and patient-friendly approach to assessing executive dysfunction in TBI patients. CAED features realistic game scenarios that replicate daily activities. Player behavior, timing, and decisions within these scenarios are tracked and, when analyzed, will provide insights into patients' cognitive function, or dysfunction. Significant progress has already been made, specifically in its software architecture and visual design, including basic systems and concept art. CAED has the potential to revolutionize neurological assessment and rehabilitation, offering a novel, technology-driven solution to improve care for individuals with TBI.

Developing Autonomous and Adaptive Systems for Space-Exploration Robotics with Neuromorphic Frameworks and Artificial Intelligence

Rithvik Suren

CREC Academy of Aerospace and Engineering, Windsor

Mentor: Thomas Brown, CREC Academy of Aerospace and Engineering

Space exploration is humanity's greatest endeavor in unknown environments. However, we face challenges in the development of independent, autonomous, and adaptive systems as we continue to identify novel regions. Currently, AI has displayed promise to predict, classify, and plan, facing challenges in rovers with stringent constraints on SWaP (size, weight, and power), performance limits of radiation-resistant hardware, and onboard processing capabilities for adaptive exploration with SLAM (simultaneous localization and mapping). As a result of such limitations, rovers such as NASA's Perseverance have restricted processing power, adaptability, and radiation-induced hardware invulnerability. The purpose of the research was to explore the potential of neuromorphic frameworks to integrate and test spiking neural networks (SNNs) for housing adaptive reinforcement learning (RL). Thereby, this novel design is aimed at enhancing power consumption, radiation resistance to extraterrestrial environments, and robust real-time processing for upcoming exploration rovers. The neuromorphic framework uses event-based processing, where tasks are handled independently and modularly, running on a Raspberry Pi. This setup aligns with the structure of SNNs. Testing procedures included system metrics tracking with RAM, CPU usage, and CPU time libraries in code. Results showcase the framework outperforming traditional parallelized algorithms in CPU time and RAM usage, with CPU time 30x faster. The neuromorphic algorithm's collocation of RAM and CPU usage was balanced at 11% for both (versus RAM: 96.3%, CPU: 6%), demonstrating that processing efficiency can be maximized with fewer resources using collocation. These results display great potential for developing compact and energy-efficient space rovers, paving the way for future space exploration.

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

Cooper Taylor

Greenwich Country Day School

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. 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 Multifunction Chemoimmunotherapy, Selective to PDAC via Its MUC1 Overexpression

Lula Wang

Greenwich High School

Mentor: 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 20 ug DOX-load was released within the same five-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-MUC1 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.

Extraction of Cellulose Nanocrystals via Sulfuric Acid Hydrolysis from Post-Consumer Cotton-Elastane Textile Blends with Elastane Recovery

Marley Wies

Greenwich High School

Mentor: Andrew Bramante, Greenwich High School

Ever-increasing textile waste contributes to a global environmental crisis. With 92 million tons of garments discarded yearly, there is a pressing need to recover cotton, which can be upcycled into high-value nanocellulose forms, with applications across industries. However, the widespread blending of cotton with elastane (spandex) complicates any recovery/reuse, as elastane becomes entangled in machinery during traditional separation processes. This research develops a scalable, sustainable upcycling pathway for extracting cellulose nanocrystals (CNCs) from post-consumer cotton-elastane textile blends. First, the sample fabric undergoes selective dissolution of elastane using N,N-dimethylacetamide (DMAc). Through filtration, cotton is separated, DMAc is recovered, and elastane fibers are isolated in a form suitable for further recycling. Sulfuric acid hydrolysis is applied to the separated cotton, producing CNC yields of approximately 55.9% (cotton basis). Dynamic light scattering (DLS) particle size analysis of the CNCs in suspension showed an average hydrodynamic diameter of 60.1 nm, which aligns with CNCs from USDA Forest Products Laboratory. This pathway outperforms the comparison method, where direct sulfuric acid hydrolysis without prior fabric separation yielded fewer CNCs (50.3%), failed to recover elastane, and produced smaller CNCs with an average hydrodynamic diameter of 51.1 nm, which falls outside of commercially preferred size ranges. The findings of this research support a feasible route for upcycling cotton-elastane blends, which are otherwise challenging to recycle. Since pre-separation enhances CNC yield and elastane recovery, this method is promising for industrial-scale applications, supporting a circular economy for textiles.

Hybrid Quantum-Classical Circuit Design: Optimizing Computational Efficiency through Integrated Reversible Logic and Hardware-Aware Quantum Processing

Harshil Yerrabelli

Conard High School, West Hartford

Mentor: Dr. Bonnie Mayer, Conard High School

The rapid development of quantum computing has introduced new approaches to optimizing computational efficiency, particularly in areas like circuit design, logic synthesis, and hardware-aware computing. However, current quantum hardware faces significant limitations, including high error rates, limited qubits, and slow execution times, making it difficult for quantum models to outperform classical computing in real-world applications. This research explores a hybrid quantum-classical approach that integrates classical circuit design principles directly into quantum algorithms to improve computational speed, accuracy, and scalability while maintaining practical feasibility. Instead of relying solely on quantum hardware improvements, this study develops hybrid logic circuits that embed reversible classical logic gates (Toffoli and Fredkin gates) into quantum computing models. These classical logic gates are naturally suited for quantum operations, simplifying circuit complexity. Additionally, we incorporate advanced circuit optimization techniques, including gate reordering, noise-aware quantum circuit transpilation, and hybrid learning models, to further reduce computational overhead. We also explore the use of machine-learning-assisted quantum optimization, testing whether combining quantum circuits with reinforcement learning can enhance problem-solving efficiency. The performance of these hybrid models is benchmarked against both traditional classical approaches and purely quantum circuits, measuring improvements in execution time, circuit complexity, and resource usage. Preliminary findings suggest that this approach offers a scalable and energy-efficient method for improving quantum computation, paving the way for advancements in low-power computing, FPGA-based circuit design, cryptographic security, and AI-driven quantum applications. This research demonstrates a practical path toward unlocking quantum computing's full potential, bridging the gap between theoretical advancements and real-world implementation.

Poster Presenters

Effects of Vitamin D Supplementation on Muscle Function in C. elegans with a Mutation in the Dystrophin Gene

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. DMD's impact extends beyond physical limitations, significantly burdening affected individuals and their families emotionally and financially. Vitamin D has improved muscle strength in children with DMD and in DMD mouse models. This research aims to investigate the potential benefits of vitamin D supplementation in a *Caenorhabditis elegans* (*C. elegans*) model of DMD. In this model, vitamin D3 (0.001-0.1 mM) improved longevity and locomotive behavior and reduced reactive oxygen species levels, suggesting potential protective effects against muscle damage. Although these initial findings are encouraging, more extensive research is necessary to comprehend the long-term advantages and molecular mechanisms underlying vitamin D3's therapeutic impact on DMD. This research provides promising preliminary evidence that vitamin D supplementation could be an affordable and accessible strategy to improve muscle function and potentially extend the lifespan of individuals with DMD. Further investigations in mammalian models are warranted to validate findings and explore vitamin D's full therapeutic potential in DMD treatment.

Studying Theories of Prebiotic Chemical Evolution and Abiogenesis by Testing the Presence of the Precursors of Life in Clay Research

Lourdes Isabella Hassan

Greens Farms Academy, Westport

Mentor: Dr. Mathieu Freeman, Greens Farms Academy

Abiogenesis, the prebiotic chemical evolution theory, proclaims that all living things originated from organic molecules and pre-life chemical reactions introduced living organisms. Taking clay and observing adsorption of primordial soup solutions can aid an understanding of whether it was possible that the conditions for life arose organically.

This experiment will mimic the environment of primordial Earth and test solutions similar to those that would have formed under these conditions. Controlled variables such as humidity, temperature, and light are important qualities that will be considered when developing this environment. The solutions used will include: (1) distilled water, cytosine, and calcium chloride and (2) distilled water, cytosine, calcium chloride, and ammonia. Three different types of clay will be exposed to these solutions: calcium montmorillonite (CCM) clay, micaceous clay, and illite clay.

Qualitative and quantitative measurements will be used to measure the water-holding capacity and qualitative properties. Scanning electron microscopy will be used to examine the surface morphologies of the clay and adsorption. Chemical composition will be determined by FTIR, identifying chemical qualities of carbon, oxygen, and nitrogen.

It is projected that the solutions will adsorb into clay structures, especially the CCM clay, showing surface morphology and exhibiting qualities that indicate that amino acids and proteins would have developed. CCM clay has the best affinities, with potential incorporated metal dictations and silicate layers. This study has the potential to address the effect of climate change on the future of our Earth.

Can Long Gaming Sessions Be a Method to Boost Mood?

Andrew Hsu

Fairfield College Preparatory School

Mentor: Dr. Panayiotis Meleties, York College, The City University of New York

Online gaming has become extremely popular in recent years at alarming rates. As a result, there has been a constant debate about whether gaming is good or bad. While some believe that gaming can be used as a form of escape or stress relief, others believe that it can lead to negative consequences. To gain insights into this pivotal topic, this study hypothesized that long gaming sessions would not have a positive effect on improving gamers' moods. To test this hypothesis, survey data published by Vuong et al. (2021) was adopted. This publicly available dataset features responses from a biodiverse group of 640 participants playing a realistic simulation game known as *Animal Crossing: New Horizons*. The survey data included 94 questions broken down into six

sections, including socio-demographic profile, COVID-19 concerns, environmental perceptions, game-playing practice, in-game behavior, and game-playing feeling. The empirical investigation involved two steps. First, the relevant information in the survey data was identified and reorganized. Next, a binary logistic model was employed to examine the relationship between extended gaming periods and gamers' moods after the sessions. The empirical results reveal that long gaming hours do not improve players' perceived moods. Stress levels and age are positively related to players' self-reported levels of bad moods. Female players have reported less negative gameplay feelings than male players. Since prolonged gaming hours do not improve players' moods, excessive gaming sessions should be avoided, and developing games targeting stress relief may be helpful to those in need.

Evaluating LYVE1 Gene Expression in Breast Cancer Using qPCR Analysis and Comparing with Hyperparameter-Tuned Models for LYVE1 Gene Expression in Pancreatic Cancer

Nivrit Ananth Iyer

Engineering and Science University Magnet School, West Haven

Mentor: Ali Senejani, PhD, University of New Haven

Cancer is a leading cause of death, with early detection rates at an all-time low. Blood tests, MRI scans, and biopsies for specifically pancreatic and breast cancer lack accuracy in early detection, with rates reaching only 87%. This study examines LYVE1, a gene with increased expression in cancerous tissues, as a potential early-detection biomarker. This study first evaluates LYVE1 expression in pancreatic cancer detection via AI models trained on a dataset published by the Spanish National Cancer Research Center. LightGBM achieved 91% accuracy in cancer detection based on LYVE1 expression, performing better than the best models trained on other biomarkers, including support vector machines for REG1B (80% accuracy) and random forest for TFF1 (85% accuracy). A study by Elsevier further confirmed that LYVE1 levels were much higher in pancreatic cancer patients, correctly identifying 96% of cases and ruling out false positives 100% of the time. The second part of this study investigates LYVE1 expression in breast cancer cells using qPCR. MDA-MB-231 (breast cancer) and MCF-10A (healthy breast) cells were initially cellularly passaged. Subsequently, RNA extraction and One-Step SYBR Green qPCR were performed using a validated LYVE1 primer pair and GAPDH as a reference gene. Results show LYVE1 is 54 times more active in breast cancer cells, mirroring its upregulation in pancreatic cancer. These findings suggest that LYVE1 may be a universal cancer biomarker in early detection and AI-assisted diagnostics. Future research will integrate LYVE1 expression data into AI models for breast cancer detection, further exploring LYVE1's role in metastasis.

Development of a Novel Deep Reinforcement Learning Algorithm for Autonomous Drone Control

Henry Jin

Greenwich High School

Mentor: Andrew Bramante, Greenwich High School

As autonomous drone technology becomes increasingly prevalent in disaster response, logistics, environmental monitoring, and other applications, the demand for scalable, decentralized control systems is rising, so that multiple drones can act in tandem, based on real-time discoveries, with minimal human intervention. This research develops a decentralized control framework that allows drones to process data locally from sensors like IMU and LiDAR and execute tasks with limited dependence on GPS or centralized coordination systems. The deep reinforcement learning algorithm (DRL) is trained in a high-fidelity simulation environment, Cosys-AirSim, and then deployed onto a drone to test in real-world environments, including open spaces, forests, and indoors, demonstrating the applicability of this research. The main performance indicators will be centered on navigation precision, obstacle avoidance, and task completion for successive refinements. This research is intended to improve the resilience and adaptability of autonomous drone systems in several key challenges: real-time responses, scalability, and operational efficiency. These aspects have the highest impact on applications in search and rescue, logistics, etc. This research places a strong emphasis on aviation safety, during both the testing and implementation phases.

Uncovering Metastasis Gene Expression Signatures and Unique Traits in Migrating Cancer Cells Using mRNA Sequencing and Transwell Assays

Yobin Kim

The Hotchkiss School, Lakeville

Mentor: Woo Rin Lee, PhD, University of Suwon

Cancer metastasis is the process by which the cancer cells migrate from the primary tumor location to other parts of the body, from the early to the later stages of the disease. This progression plays a large role in cancer mortality. Therefore, understanding

the molecular determinants that distinguish cells with high metastatic potential from their low-metastatic counterparts is critical for the development of improved diagnostic, prognostic, and therapeutic strategies. This study investigated the molecular characteristics of highly metastatic cancer cells selected via transwell assays from three human cell lines (A172, MCF7, and MDA-MB-231). This study aimed to determine specific gene expression profiles that define high- metastatic and low-metastatic cells. After three rounds of transwell selection, the cells that passed through the transwell membrane had elongated shape, indicating increased motility. The RNA-seq analysis identified differential gene expression signatures associated with metastasis, identifying 11 significantly upregulated genes and 209 downregulated genes. These changes in the expression of genes are involved in cell proliferation, biosynthesis, and genomic stability, as well as a decrease in immune response and antigen presentation. These changes indicate that the metastatic cells acquire a new environment, restructure their components, and avoid immune recognition to enhance invasive growth. By integrating phenotypic and transcriptomic data, this work highlights key molecular targets and pathways associated with metastasis. This result provides a foundation for developing more effective diagnostic markers and personalized therapeutic strategies.

Making a Real-Time Water Quality Monitor: An Arduino-Based System for Measuring Water Contamination

Sowa Laryea-Adjei

King School, Stamford

Mentor: Dr. Victoria Schulman, King School

Water contamination is a critical global issue, with around 2.2 billion people lacking access to safe and clean drinking water sources. Bacterial contamination from *E. coli* and *Salmonella* poses serious health risks, including infections and potentially fatal cholera. Contrary to popular belief, this issue isn't only prevalent in underdeveloped countries, but also in 40% of rivers and 46% of lakes here in the United States. Despite the importance of regular water quality testing, high-accuracy equipment remains prohibitively expensive, particularly in lower-income regions. To address this issue, a compact, Arduino-powered water quality testing device was developed to measure parameters such as pH, oxidation-reduction potential (ORP), electrical conductivity (EC), total dissolved solids (TDS), and turbidity. The device takes the readings of the sensors and gives a result stating whether the water is of good quality or not. The device aims to offer an affordable and portable solution for water quality monitoring. The circuit and 3D prototype were designed using Tinkercad, after which I soldered the required electronic components and constructed the physical prototype with foam cores. I then purchased distilled water and gathered samples from two distinct water sources: Cove Island in Stamford, Connecticut, and Poughkeepsie, New York. After comparing the readings of the device with a store-product water quality tester, the prototype still needs more modifications on some sensors, but overall displayed accurate information. This project has the potential to improve water monitoring practices, especially in resource-limited regions, by providing a user-friendly tool for regular water quality assessments.

Modeling Breast Cancer Cell Invasion Using Active Brownian Dynamics

Nicholas Lu

Amity Regional High School, Woodbridge

Mentor: Dr. Corey S. O'Hern, Yale School of Engineering and Applied Science

Cancer cell invasion into mammary adipose tissue controls the progression and metastasis of breast cancer. However, it is difficult to obtain time-dependent, three-dimensional data on breast cancer invasion in vivo. As a result, a collaborating research group had developed an in-vitro experimental system where cancer cells migrate within an artificial tissue composed of hydrogel beads embedded in a collagen matrix. This project sought to develop computer simulations that could quantitatively capture the spatiotemporal dynamics of cancer cells migrating within the bead-collagen matrix. The active Brownian particle simulation first was employed to model the migration of cancer cells without the collagen fibers. Then, additional features were introduced into the model to improve the comparison to the experimental results. For example, preliminary studies had shown that the collagen fibers are denser and more aligned in the narrow regions between the spherical beads, which suggests that the cancer cells can migrate faster and more persistently in these regions. Thus, in the next step, the collagen matrix was effectively modeled by varying the migration speed and direction of the cancer cells based on the local packing fraction of the beads. After developing the simulation, the migration patterns of the simulated cells were analyzed by plotting the mean-squared- displacement (MSD) and comparing it to the MSD plots of the empirical data. The simulated trajectories had moderate to high similarity to the empirical data, with the MSD curve having an error of less than 15%. While relatively accurate, the simulation still needs further improvement. Future studies could explicitly model collagen matrices to better represent breast cancer cell invasion. New simulations could model collagen matrices explicitly rather than implicitly to achieve this. Should an improved simulation be developed, studying breast cancer invasion could become significantly easier, which could eventually assist in developing novel methods to treat breast cancer.

Research on Autoimmune Disease Spectrometer (RAD-Spec): A Machine-Learning–Based Application for Improving Accessibility to Research on Autoimmunity

Victoria Makarov

Laurel Springs School (online), Ojai, CA

Mentor: Vera Ulanovskaya (parent/guardian)

It's estimated that 5% to 10% of the global population suffers from some type of autoimmune disease (AD), but despite this prevalence, the general research effort into finding a cure for their symptoms and underlying causes has been very disorganized. For this reason, many in the field see part of the solution as being a public database of indexed scholarly work that patients, doctors, and researchers studying autoimmunity can use to stay updated on advancements and discoveries. While organizing this literature would be very time consuming if done by hand, machine learning could automate this task. One candidate that stands out is Bidirectional Encoder Representations from Transformers (BERT), a relatively lightweight large language model (LLM) that has widely proven to be effective at natural language processing classification tasks, especially if pre-trained on a domain-specific corpus. However, the effectiveness of BERT and its biomedical-specific variants when classifying AD research publications has been unexplored. This study first quantified how much BERT's performance improves during classification tasks with AD-focused texts when pre-trained on a biomedical corpus, finding that each biomedical variant—BioBERT, ClinicalBERT, BlueBERT—outperformed the basic BERT model and had an industry standard accuracy (>70%), although there was no consistent top performer among each task. Next, these findings were implemented into the Research on Autoimmune Disease Spectrometer (RAD-Spec), a web-app featuring interactive scatterplots (displaying the classified data) that help users explore the AD research publications nested under specific labels.

Analyzing the Relationship between Priming and People's Accuracy, Confidence, and Speed in Insight Problem-Solving

Salma Maklad

Amity Regional High School, Woodbridge

Mentor: Dr. Jaan Aru, University of Tartu

Problem-solving is a highly needed and fundamental cognitive function in humans. Insight is characterized by a solution appearing suddenly when solving a problem and is often accompanied by a feeling of confidence and pleasure. Insight is a crucial part of problem-solving, allowing humans to make breakthroughs when solving difficult problems. Priming is defined as something done for the improvement of processing a stimulus or task prior to introducing it. Although there is a variety of research on insights, priming, and problem-solving, there is little research on how priming affects insight due to the difficulty of creating an environment where one can have an insight moment in a lab. The purpose of this research is to analyze the relationship between priming and people's accuracy, confidence, and speed in insight problem-solving. It was hypothesized that if participants were primed with an AI-generated short story prior to completing the insight problem, then they would have increased speeds, confidence, and accuracy in doing so because the purpose of priming is to improve processing. The independent variable of this experiment was percent primed, and the dependent variables were the suddenness in which the solution came to the participants, the accuracy of their guesses, and the confidence of participants in their answers. Participants from a high school in Connecticut (n=8) completed an AI-generated short story prior to completing the constellation-image task. Comprehension questions were asked to ensure that participants read the story. Those who scored 50% or higher were placed in trial 1, and those who scored lower were placed in trial 2. After that, participants viewed 23 constellation images and guessed the hidden image within them. Trial 3 was made up of participants from a university in Tartu, Estonia (n=79), who only completed the constellations task. Data on participant time, confidence, and accuracy with the constellation images was collected through the software used. Three graphs were made depicting the average suddenness, confidence, and accuracy across trials. Two ANOVAs and one chi-squared were conducted to determine statistical significance ($p < 0.5$). The student conducted research for trials 1 and 2, and the mentor provided data on participants for trial 3 for the student to analyze. Results found that priming did not positively impact insight problem-solving as initially hypothesized. Priming negatively affected participants' accuracy and showed no significant effect on confidence or suddenness of insight moments. The results of this research challenge past priming studies and may guide future research to take different approaches when approaching this topic.

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

Tyler Malkin

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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 (~45 nm) 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.

Using Piezoelectric Sensors to Harvest Energy from Automobile Tires and Road Surface

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Piezoelectric sensors can be used to harvest energy from automobile tires and the road surface. The idea would be that the tires from cars would run over the piezoelectric sensors in the road and generate energy from applied stress. The stress may be caused by pressure, acceleration, or temperature change. This investigation explored the effects of mass and speed on the response of the piezoelectric sensor when voltage and current were measured. Speeds of 0.15 m/s and 0.35 m/s were investigated, and it was found that the faster the car was traveling, the more voltage, and thus the more power, was produced. The second effect was added mass, and the testing ranged from no added mass to 1,000 g of added mass to the car. During these experiments, it was found that the distribution of the load in the car was significant, and so the added mass was investigated both as a point load and a distributed load. It was found that the more mass added to the car, the larger the voltage and power response from the sensor, with the distributed load always higher than the point load for the same added mass. In conclusion, piezoelectric sensors embedded in public roads are a viable way to create renewable energy to sustain the world's growing energy demands.

Comparative Analysis of Virulence and Antibiotic Resistance Genes in Stimulated vs. Unstimulated Saliva to Assess Observed Oral Disease Risk

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There are two commonly performed methods of collecting saliva: with, and without, the stimulation of salivary glands. These methods have been previously suggested to produce varying results, which can influence diagnostic results, and little research has been done to evaluate whether stimulated or unstimulated saliva influences the observed risk of illnesses. Understanding how saliva stimulation affects diagnosis with regards to susceptibility of disease better guides future oral sampling techniques. Previous research has suggested that stimulated saliva enriches taxa associated with dental caries, which may contain more antibiotic resistant genes as caries develop in the oral cavity, and thus, it was hypothesized that stimulated saliva suggests a greater disease susceptibility. The perceived risk of oral disease was represented by the quantity of antibiotic-resistant and virulence genes. Both stimulated and unstimulated oral samples were collected from dental patients via cotton swabs, first unstimulated, then stimulated saliva after stimulating salivary glands. 16S rRNA sequencing and metagenomic shotgun sequencing produced data to identify present bacterial species after amplification of extracted DNA. CARD and VirulenceFinder screened for antibiotic-resistant genes and virulence genes. Relative abundance was used to quantify the incidence of virulence genes and antibiotic resistance, and statistical analyses such as paired t-tests established whether there is significance behind the

metagenomic data. This study suggests that unstimulated saliva samples exhibited a greater diversity and prevalence of the antibiotic resistant gene *phosphinothricin acetyltransferase* (PAT), potentially capable of conferring resistance to aminoglycosides and acetylating toxic L-PPT, suggesting a heightened susceptibility to oral disease compared to stimulated saliva.

An Effective Water Treatment Method: Adsorption of Nickel(II) Ions in Water Using DNA-Wrapped Carbon Nanotubes

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As of 2024, one in four people globally lack access to safe drinking water. According to the 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. Current water treatment methods such as ultrafiltration or ion exchange are costly and high-maintenance. Recently, adsorption of chemical pollutants in water has earned much attention because of its low cost, high efficiency, and fast reaction time over a variety of environmental conditions. Adsorption is the chemical or physical adherence of a smaller molecule onto the surface of a larger adsorbent. Herein, carbon nanotubes (CNTs), carbon ring arrays rolled into tube-like structures at the nanoscale, were wrapped with single-stranded DNA and used as adsorbents. CNTs have noteworthy properties such as high thermal stability, tensile strength, and surface area, making them versatile adsorbents. DNA wrapping resolves two major challenges CNTs face: insolubility and aggregation among CNTs, which can greatly hinder efficacy. We aimed to establish DNA-wrapped CNTs as competent adsorbents. Concentration of nickel(II), or Ni^{2+} , ions in aqueous solution was measured before and after CNT incorporation to determine adsorption effectiveness. It was found that 1.2×10^{-5} μmol s CNTs adsorbed 53 μmol s Ni^{2+} . This establishes DNA-wrapped CNTs as effective adsorbents, particularly of toxic metal ions in water. Given these findings, this approach has the potential to treat large bodies of metal-contaminated water if scaled up on a commercial level.

Examining the Cognitive Impact of Lower Inhalation Levels of Chlorine Gas on Drosophila melanogaster

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Chlorine, commonly used for pool sanitation, can be released and inhaled as a gas during pool cleaning. Once inhalation occurs, chlorine gas reacts with moisture in the respiratory tract to form hydrochloric and hypochlorous acids, similar to those found in pools. These reactions can cause a range of respiratory symptoms, depending on gas concentration. Studies show that exposure levels between 1 and 10 ppm can cause physical symptoms such as eye and nasal irritation or sore throat. However, limited information is available on the cognitive effects. Exposure above 15 ppm, on the other hand, can result in severe cognitive impairments, including impaired balance and slower reaction times, as well as physical symptoms like visual disturbances and breathing difficulties. This study addresses a critical gap in understanding the long-term cognitive effects of low-level chlorine gas exposure. Using *Drosophila melanogaster* as a model organism, it examines the impact of two controlled chlorine gas exposure levels, 3–10 ppm (average 6.5 ppm) and 10–20 ppm (average 15 ppm), on cognitive and motor functions. Response tests, including a volatile chemical assay and a negative geotaxis assay, were used to gather data. These results were compared to unexposed control groups to assess potential cognitive decline. The study hypothesizes that higher chlorine gas exposure will result in decreased behavioral responses in *Drosophila melanogaster*, indicating cognitive impairment, with longer exposures causing greater declines. These findings could inform future research and regulatory measures to enhance public safety regarding chronic low-level chlorine gas exposure.

Equine and Human Heart Rate Variability Synchronization as a Model for Potential Atrial Fibrillation Treatment

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Atrial fibrillation (AF), the most common type of cardiac arrhythmia, is a growing global crisis. In 2017, 37.574 million cases of AF were diagnosed, and projections forecast an increase by more than 60% by 2050. Yet currently available treatments are invasive and yield poor prognoses. Relatedly, studies have shown that equine hearts synchronize with their herd members' heart rhythms, and cause nearby human hearts to transmit at their same frequency. But it was unclear if a specific beat-to-beat correlation existed between human and equine hearts, such as would be applicable to AF treatment. This study began exploration of a novel AF treatment method, using the equine heart as an external "device" which can impact the rhythm of the human heart,

noninvasively correcting an arrhythmia such as AF. It aimed to demonstrate that proximity to an equine's heart causes synchronization of the human participant's heart rate variability (HRV), or variability in heart rate interbeat intervals, with the equine's. This study used Polar H10 electrocardiogram monitors to measure the HRVs of both equines and humans while in proximity. Kubios HRV analysis software calculated RMSSD, SDRR, and pNN50 ratios, which indicate heart rate beat-to-beat activity over time, for both data sets, and case study analysis indicated a statistically significant correlation between these analysis values in the equine and human participants. This indicates the equine heart's ability to precisely influence human heart rhythms. This project contributes towards the eventual goal of building an equine-heart-inspired medical device that allows for effective AF treatment.

Mitigating Heat Stress in *Saccharina latissima* and *Gracilaria mammillaris*: The Role of Nutrient Additives in Enhancing Resilience to Climate Change

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Saccharina latissima and *Gracilaria mammillaris* are ecologically important primary producers that provide essential nutrients to surrounding ocean ecosystems. Specifically, *S. latissima* provides habitat, protection, and structure for abundant marine life, impressively ranging along 25% of Earth's coastlines. Macroalgae has recently gained popularity as a potential renewable and cost-effective source of biofuel, feedstock for agriculture, and biomanufacturing material, providing additional interest for efficient cultivation techniques. However, due to anthropogenic changes such as increased water temperatures and ocean acidification, these algae are predicted to experience higher mortality rates, eventually leading to cascading and catastrophic impacts in surrounding ecosystems. Here, we show the effect of various nutrient additives, namely vitamin C in the form of L-ascorbic acid, zinc gluconate, and manganese gluconate, on the growth rates and photosynthetic efficiency of algae. The statistical analysis did not reveal any significant differences between experimental groups during a four-week controlled growth experiment; however, the additives were successful in mitigating mortality under heat stress. Vitamin C benefited both species' photosynthetic efficiency under thermal stress, implying a general ability to function as an antioxidant, while the manganese and zinc treatment only benefited *G. mammillaris*. These additives likely facilitated growth through increasing pathogen resistance and functioning as a redox buffer. These results demonstrate the potential for nutrient additives as a possible method of mitigating the effects of rising ocean temperatures on kelp in the era of climate change. In the future, these results could be applied to offshore wind turbines as an additive to a limewash or tile, boosting the functionality of these existing structures to farm seaweed in open waters. This support to seaweed communities can help offset carbon emissions and facilitate a balanced surrounding ecosystem, which will become increasingly critical as climate change progresses.

Evaluating Market Efficiency through Deep Learning: A Performative Analysis of LSTM Neural Networks, Actor-Critic Reinforcement Learning Models, and Technical Indicators

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Stock market inefficiencies provide opportunities for traders to achieve returns above market averages. However, these inefficiencies are quickly exploited, making their identification and practical application challenging. Previous studies have utilized long short-term memory (LSTM) neural networks for stock price prediction, yet they often face two critical limitations: reliance on normalization methods that incorporate future data, rendering them unsuitable for real-world use, and a focus on prediction accuracy without addressing how these predictions translate into actionable strategies.

This study addresses these limitations. It employs a normalization technique that relies solely on historical data, ensuring real-world applicability. Second, it integrates LSTM neural networks with a trading framework to bridge the gap between theoretical predictions and practical decision-making. Additionally, the research explores the comparative effectiveness of conventional and unconventional technical indicators in identifying market inefficiencies.

Using EUR/USD data at 15-minute intervals from 2019 to 2024, this study develops a dual-model system consisting of an LSTM-based predictor and a Deep Q-Network (DQN) reinforcement learning agent. The LSTM model forecasts price movements, while the DQN agent translates these predictions into optimized trading decisions.

Results indicate that while unconventional and conventional indicators yield comparable predictive performance, integrating reinforcement learning with LSTM-based predictions leads to significant improvements in trading outcomes. The trained model consistently outperforms both successful discretionary traders and even the top-performing hedge funds.

By combining technical indicator analysis with actionable trading strategies, this research advances the practical applications of artificial intelligence in finance, providing valuable insights for both academic research and professional trading practices.



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