Virginia Junior Academy of Science
Research Symposium and 82nd Annual Meeting

May 2, 2026 - General Session/Jeffers Lecture
May 2, 2026 - Student Presentations
May 18, 2026 - Awards Ceremony

Proceedings of The Virginia Academy of Science
In-person Research Symposium, hosted by
Hampden-Sydney College
Proceedings published on the VJAS website www.vjas.org

The Virginia Academy of Science

The Virginia Academy of Science (VAS) is the fifth largest state, region, or city academy of science in the U.S.; it was founded in 1923 to promote the civic, academic, agricultural, industrial, and commercial welfare of the people of Virginia. Exemplary programs have included Flora of Richmond and Vicinity, Published, 1930, the first comprehensive multidisciplinary studies of the James River Basin and the Great Dismal Swamp, volunteer research assistance to Virginia in the instance of the Kepone pollution disaster, and leadership in establishing the Science Museum of Virginia.

Fall Undergraduate Research Meeting:
The focus of this meeting is support of undergraduate student research. Specific details about the 2026 Fall Undergraduate Research Meeting, including the location and date will be made available on the VAS website (www.vacadsci.org) during the summer.

The Virginia Junior Academy of Science

VJAS is a national model for the new and renewing state junior academies and has been ranked among the top three in the nation for over two decades. Through VJAS and other programs, VAS annually reaches over 40,000 Virginia middle and high school students. Hundreds of volunteers make it possible for Virginia secondary students to experience these activities.

Hampden-Sydney College

The Virginia Academy of Science and the Virginia Junior Academy of Science express their sincere appreciation to the College of Hampden-Sydney for the generous support in providing symposium meeting rooms and services.

The College of William & Mary

The Virginia Academy of Science and the Virginia Junior Academy of Science express their sincere appreciation to The College of William & Mary for the generous support in providing web conferencing meeting rooms and services.

A Tradition of Excellence, A Commitment to Action

Contributors and Supporters

The Virginia Academy of Science and The Virginia Junior Academy of Science notes with appreciation the contribution and support of hundreds of individuals and dozens of organizations to the success of this year's Research Symposium and Annual Meeting.

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VJAS Committee Chair's Welcome

Dear Virginia Junior Academy of Science participants,

On behalf of the Virginia Junior Academy of Science Team and Committee, I would like to extend the warmest welcome to each and every one to the 85th Virginia Junior Academy of Science (VJAS) Annual Meeting and Research Symposium.

First, I would like to congratulate our student finalists. Despite the challenges, each one of you strived to conduct the best possible scientific research experiments in a variety of different settings and circumstances. Your valiant and resilient efforts shine through brightly – as a VJAS student finalist, your research papers have been read thoroughly and were selected by a rigorous panel of evaluators from across the state. This is a great accomplishment, and you should be proud of your research and academic success!

As we commence our in-person Annual Meeting and Research Symposium, I would like to share some thoughts with you. This past year, more so than any others, we have seen a rise in the stake – the importance – of the role science and research plays in our society. Scientists from all corners of the Earth joined together and responded to meet a daunting challenge. We have acted as one to address a global crisis that discriminates against none.

This atmosphere of cooperation and working together as collaborators and not necessarily viewing each other as competitors all the time, is something we scientists need to continue promoting. Yes, there is a balance – but our society will greatly benefit, and the frontiers of knowledge further breached into new territories faster if we work together more often. Therefore, I would encourage you to view each other during this virtual Research Symposium as future collaborators and colleagues, partners of the future, rather than as competitors.

As you move onward into your collegiate and professional careers, I understand that some of you will continue the path of a scientist, but just as many will choose different routes in medicine, teaching, politics, and so on. What we hope to convey at this year's Annual Meeting is that no matter which career route you choose, your fundamental understanding of science and how research is conducted to bring progress, will be invaluable and become a lifelong foundation. And remember, you can always be an advocate in promoting science and research, wherever you are.

In closing, I hope the 85th VJAS virtual Annual Meeting and Research Symposium is an enriching and engaging experience for everyone. Once again, welcome and congratulations on your accomplishments.

Sincerely,

Susan P Booth

Director, VJAS Committee

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George W. Jeffers Memorial Lecture

Combining Traditional Knowledge with Western Science

Community-Based Remote Sensing in Western Alaska

Want to see how science helps communities—right now?

What happens when we combine **drones**, **satellites**, and other tech with **local knowledge**? This talk shows how researchers, students, and Alaska Native communities' team up to understand environmental change and protect cultural heritage in some of the most remote places on Earth.

3 Big Things You'll Take Away

1) Climate change you can measure

How remote sensing helps track environmental shifts and how climate change is affecting the land.

2) Tech that supports people in real life

How community-based approaches can assist with **Search and Rescue operations**.

3) Protecting culture with science + collaboration

How teams help protect important cultural sites like the 500-year-old Nunalleq village.

Meet the Speaker

Sean Gleason, Ph.D.

Elliott Associate Professor, Hampden-Sydney College
Co-founder & Head of Research & Development, Nalaquq, LLC (Alaska Native-owned technology startup in Quinhagak, Alaska)

Research focus: geospatial science, remote sensing, and community-based knowledge in Indigenous Arctic contexts.

If you're into… you'll like this talk

STEM • Environmental science • GIS & mapping • Drones/UAVs • Climate • Anthropology • Community partnerships • Research careers

Middle School Sections

Animal & Human Sciences (MS AH)

First Place
Mahesh Umika, George H. Moody Middle School
The Effect of Different Types of Music on Cognitive Abilities in School Kids

Cognitive functioning is the mental process that allows people to carry out daily activities like storing, processing, and using learned information. However, various external and internal factors, including environment and health disorders, can affect cognitive abilities. The present study evaluates how exposure to different types of music affects cognitive performance in school children, a group that requires them to stay focused and excel in academic activities. The study examined two common types of music - Vocal, Instrumental, and a Control (no music) - before playing a cognitive game. The hypothesis of this study was that if the children listened to instrumental music versus vocal music for 15 minutes, then they would receive higher scores on the tested cognitive game. Ten children aged 13-15 years listened to Vocal, Instrumental, or no music (Control) for 15 minutes, followed by playing the video game three times for 3minutes or until the participant dropped out. The three video game scores for each subject were compiled, and the mean score was calculated using Excel software. The results indicated that average performance was the highest for Instrumental (2113) and the lowest for Vocal (1886), although they did not differ meaningfully from the Control (1918). Since there was a wide range of scores for each subject, the results were also normalized to evaluate the treatment effects within each subject. Overall, the normalized mean for all 10 subjects for Instrumental was 1.26, and for Vocal was 1.21, indicating that both treatments seemed to help improve performance when compared to the Control (1.0). While both treatments resulted in a normalized mean value greater than 1, whether they were significant for the majority of the population requires more participants to be included in the study's in-depth analysis, given the higher variability in scores. Overall, the findings do not fully support the hypothesis that listening to music — either vocal or instrumental—before a cognitive activity such as playing video games improves performance.

Second Place
Bhatt Medha, George H. Moody Middle School
The Effect of Isopropyl Alcohol in Hand Sanitizer on its Efficacy in Delaying the Presence of Bacteria on the Hands

As the spread of bacteria becomes prominent in the 21st century, alcohol-based hand sanitizers are especially important where soap and water are not available. With this, individuals have not considered the impact isopropyl alcohol has on the efficacy of the hand sanitizer they use. The purpose of the experiment was to figure out how the concentration of isopropyl alcohol in hand sanitizer can affect the amount of time it takes for bacteria to form on the hands, with prior research suggesting that isopropyl alcohol concentrations of 60-75% optimize sanitizer efficacy. The experimenter’s hypothesis stated that if hand sanitizer with a high isopropyl alcohol concentrate is used, then it would take a longer amount of time for bacteria to form. The experiment tested four sanitizer formulations containing 30%, 50%, 60%, and 75% of isopropyl alcohol that were each applied to

volunteering participant's hands before swabbing onto agar plates that were monitored every 12 hours for 10 days. Of 20 plates, 8 showed bacterial growth while 13 showed no bacterial growth. Higher alcohol concentrations yielded fewer growth-positive plates and progressively longer times to form their first bacterial colonies, in which the 30% concentration had 4/5 growth-positive plates with the first signs of growth mainly at 72 hours, the 50% concentration with 2/5 positive plates forming their first bacteria colonies from 72–84 hours, and the 60% concentration and 75% concentration showing 1/5 growth-positive plates forming their first signs of bacterial colonies from 96-108 hours after testing. These results supported the experimenter's hypothesis that higher alcohol levels, particularly 75%, are more effective at delaying bacterial growth, while limitations such as time intervals and slight fungal intervention suggested the need for more controlled future studies.

Third Place

Heng Nicholas, George H. Moody Middle School

The Effect of Different Amounts of Salt on Brine Shrimp Hatch Rate

Aquaculture widely uses brine shrimp to provide a convenient form of food for fish and crustaceans. However, these types of shrimp can be put to use in many other areas. Fish tanks and small aquariums can use brine shrimp as a more efficient source of food than processed food. The main reason brine shrimp isn't very widely used is that they usually require an incubator and precise temperatures. This experiment was meant to figure out a way to hatch brine shrimp efficiently without the use of advanced technology. For this experiment, the researcher hypothesized that more brine shrimp would hatch with more salt. This hypothesis was backed up by the fact that brine shrimp are most commonly found in saltwater environments, such as Mono Lake in California. The experiment had 4 levels of the independent variable: 10, 20, 25, and 30 grams of salt in a liter of water. There was also one control group. The researcher would put salt and ¼ teaspoon of brine shrimp eggs in each container and let them sit for 24 hours. Results from this experiment were that the hypothesis was correct and that more salt resulted in a higher hatch rate. The 30g concentration had a mean hatch rate of 0.0225%. The container with no salt did not hatch any brine shrimp, leading to the conclusion that brine shrimp do not hatch without salt. Although the experiment proved the hypothesis correct, there were many flaws and limitations. The ideal temperature for hatching was not achieved, and there wasn't an optimal amount of light level or air flow. To improve this experiment, maintaining a 25–27-degree Celsius temperature would be necessary along with proper aeration.

Honorable Mention

Shrestha Annika, George H. Moody Middle School

Effect of Colored LED Lighting on Sleep Quality

The project was conducted in order to discover how much environmental features can impact a person's sleep quality. For the procedure, the experimenter was exposed to four different LED colors, with them being no light, red, blue and white light for 20 minutes. The experiment was carried for 40 days, with ten trials per color. During that time, the sleep quality factors (sleep efficiency, sleep latency, sleep duration and wake after sleep onset) was measured on a watch. The project originally proposed that if the experimenter was exposed to different LED lights, then the cooler colors would have better effects on sleep

quality than warmer colors. After the experiment, it was discovered that both no light (control) and red light had better overall averages for sleep quality, compared to blue and white. This was despite the original prediction, due to how warmer tones and no color are more successful for producing melatonin for the body, as backed by research. Since an individual's sleep quality can also be affected by other environmental features, other potential experiments could be conducted with the main feature focusing on sleep quality to understand how much factors can affect sleep.

Chemical Science A (MS-CS)

Joyce K. Peterson Award
First Place
Madurantakam Suveer, George H. Moody Middle School
The Effect of Rapid and Slow Gelation of Sodium Alginate on the Physical Properties and Dye Retention

Soft gels are one of the most popular forms of orally administered medications due to their ability to carry a variety of drugs, ease of swallowing, and faster action. Animal-derived gelatin is the main ingredient in soft gels, but it is not a viable option for some people due to allergies, religious beliefs, and lifestyle choices. The goal of the study was to evaluate whether calcium alginate could be used as an alternative to gelatin. Two gelation methods, slow and rapid, were used to cross-link sodium alginate using calcium chloride. The study hypothesis was that if the sodium alginate undergoes slow gelation, then it will be able to retain more dye when compared to sodium alginate that undergoes rapid gelation. Dye retention, weight, and shape of crosslinked gels were measured in this experiment. Photos were taken to observe and measure these properties. Dye retention was quantified using the HSB stack format in ImageJ. The weight was measured using a digital weighing scale, and the shape was qualitatively compared between the two groups using the photographs. The results indicate that slow gelation had significantly higher saturation when compared to the rapid gelation, and there was not much difference in the weight between the two groups. In addition, slow gelation gels had a defined and consistent shape compared to the rapid gelation. Overall, results indicate that slow gelation is a better strategy and can be used to replace gelatin in soft gels.

Second Place
Nair Rukmini, George H. Moody Middle School
The Effect of Light Intensity on Color Retention in Oil Paint

Restoring oil paintings is crucial in the artistic aspect of the world as numerous paintings often get thrown out or get repainted with the wrong colors and oftentimes doesn't show their true potential. This experiment tested different light bulbs with various light intensities ranging from 1100 lumens to 2100 lumens on 40 canvases painted with the color ultramarine, blue. The hypothesis states that the 2100 lumen light bulb will lighten the ultramarine color the most compared to the 1100 and 1600 lumen light bulbs. The preparation of this experiment required parental supervision for the wire work, an environment with controlled light, and taking care of the paints with proper care. The independent variables in this experiment were the levels of light intensity, including the 1100, 1600, and 2100 lumen light bulbs. The dependent variable in this experiment was

the color retention in the oil paint, measured using the canvases. A control group was used with 10 canvases having no light shun on them. The study ran through 40 canvases painted with the blue color throughout a 4-week process. The results showed that the light bulb best suited for preserving oil paintings would be the 1600 lumen light bulb due to its similarities in RGB levels to the control group. The hypothesis was proven to be right in the experiment due to the 2100 lumen light bulb, lighting the canvas's color the most. In this study, it is shown that the light bulb most effective in not fading the paint would be the 1600 lumen light bulb, and the light bulb that lightened the color the most was the 2100 lumen light bulb. However, the 1600 lumen light bulb ended up looking the darkest visually, even though statistically it was the 1100 lumen light bulb. This study showed that 1600 lumen light bulbs are the best for not fading oil paintings over time.

Third Place

Kumar Shiven, George H. Moody Middle School

The Effect of Different Bases on Stabilizing the pH Levels in Water

Ocean acidification is a growing problem around the world, causing water species to die and even become extinct, because of our errors. The purpose of this experiment was to figure out a safe and practical way to limit the issue of ocean acidification by using different bases. The bases were poured from the same height, and they all had the same amount added, with 50 mL of each substance added to a liter of water. The researcher predicted that baking soda would be the closest to stabilizing the pH levels towards the original value. The results of this experiment supported the researcher's hypothesis with baking soda being the closest, and unsweetened almond milk was the worst, with it making the water even more acidic. The laundry detergent and soapy water made the water's alkalinity increase; however, these substances raised it too much to be considered. Experiments done before this experiment had similar results, with baking soda being the best at stabilizing pH levels. Another base that did even better was lime (from limestone). The researcher realized this experiment proves that if a bit less baking soda is added to the water, the water could be stabilized back to its original alkalinity.

Honorable Mention

Sheth, Vraj, George H Moody Middle School

The Effect of Mild Chemicals on the Decomposition of Bamboo Straws

The project was conducted to discover potential solutions to the long degradation system of bamboo straws which are littered. The researcher had pre-determined that the solution of sodium bicarbonate sodium percarbonate would be the most effective solution in doing this. For the current investigation bamboo straws were cut in half and measured before soaking in different solutions including sodium bicarbonate sodium percarbonate, vinegar, calcium hydroxide, sodium carbonate hydrogen peroxide as well as the control water. These were heated at different temperatures such as 80, 90, 100 and 110 degrees Fahrenheit. Once soaked, their mass was measured again with an electronic scale and statistics were calculated. The researcher found that the most effective solution was sodium bicarbonate sodium percarbonate with an average percent change of 75.48% from the before to after mass. Similarly, the average mean change for Vinegar was 0.7925. Secondly, the other solution of hydrogen peroxide + sodium carbonate had an average mean change of 0.62155. The third solution, Calcium hydroxide, had a mean change of

0.393375. These values show how the solutions are slowly decreasing from the most effective to least effective. Along with this the average mean change was significantly high being 1.726675. This review was necessary to identify effective enhancement approaches to make bamboo easier to degrade with unharmful chemicals.

Honorable Mention

Gauri Varma Jayakrishnan, George H. Moody Middle School

The effect that different water pollutants have on the water's surface tension.

This study investigates how the purity of water affects its surface tension, a critical physical property influencing various natural processes and industrial applications. The research tested five different substances, soap, oil, salt, sugar, and distilled water, to determine their effects on surface tension as measured by the number of drops formed per milliliter (mL) of liquid. The hypothesis proposed that impurities like soap or oil would decrease surface tension compared to pure water. Experimental results indicated that the salt solution displayed the highest average surface tension at 26.4 drops per mL, outpacing distilled water, which was 23.8 drops. Conversely, the vegetable oil solution showed the lowest surface tension, averaging only 11.9 drops per mL. These findings emphasize the complex interactions between water and dissolved substances, indicating that salt enhances surface tension by strengthening intermolecular forces, while oil disrupts them. This research highlights the importance of water quality in environmental and industrial backgrounds and gives insights into how different and unique compounds can change the important properties of this vital resource.

Computational Biology (MS CB)

First Place

Nguyen Isabella, Yorktown Middle School

Cracking the Code of Suicide Risk: Aptamer-Based Profiling of Heat Shock Protein 90 Beta (HSP90β) to Predict Suicide

Around 740,000 cases of suicide are reported annually. This estimates a death every 43 seconds. People feel the need to commit suicide because of severe depression that makes them think help is nonexistent, and they could not escape. Current detection methods rely on behavioral screening, which often misses early detection. Therefore, there is an urgent need for a blood-based detection method for the early detection of suicidal tendencies. Recently, research highlighted the involvement of heat shock protein 90-beta (HSP90AB1) in cellular stress response linked to suicidal behavior. Heat shock proteins are proteins that respond to stressors, such as heat and nutrient deprivation, and help cells respond to these stresses while being divided into groups based on their molecular function and weight. I hypothesize that heat shock protein 90-beta (HSP90AB1) plays a critical role in stress responses linked to suicidal behavior. By identifying binding interactions with potential small molecules, I aim to support early detection or therapeutic intervention. This study explores the potential of detecting HSP90AB1 as a molecular biomarker for early suicide risk prediction using aptamer-based docking simulations. In this research, I used various computational methods to understand the interactions between aptamers and proteins. These aptamers are small segments of nucleotides conjugated with fluorescent dyes. Our results show that aptamer S65 is the strongest binder to the predicted active

site, suggesting its potential for use in early diagnosis. Future work includes experimental validation and toxicity assessment of the selected aptamers.

Second Place

Sharma Shaurya, George H. Moody Middle School

The Effect of Dopamine Exposure on Electroencephalogram Power Spectral Density

The experiment was conducted to find a solution to cure or treat brain disorders. In the experiment, a simulated brain model was exposed to either no dopamine exposure, low dopamine exposure, medium dopamine exposure, or high dopamine exposure, and the model's EEG PSD was recorded. The experimenter used the Python programming language (v3.11.1) along with The Virtual Brain Python packages (tvb-library v2.10.0 and tvb-framework v2.10.0) and all their dependencies. A custom version of the Wilson-Cowan model was used to simulate dopamine. The research hypothesis was: If dopamine exposure is increased, then electroencephalogram power spectral density will decrease. This hypothesis was chosen because rats have similar brains to humans, and studies using rats showed that increased dopamine leads to decreased EEG PSD. In descending order by mean EEG PSD, the IV levels ranked as follows: high dopamine, no dopamine, medium dopamine, and low dopamine. There was a notable difference between the IV levels' variances, seeing that the maximum f-ratio was ~3.3. The experimenter used a Welch's ANOVA test and got a p-value of ~0.781, which was well over the α value of 0.05. As such, the null hypothesis could not be rejected, and the research hypothesis was not supported. It is worth noting the model used to simulate dopamine was very basic. Future study on this topic should explore different factors that may affect EEG (like brain disorders) and different brain metrics (like blood oxygen level dependent signals).

Third Place

Reddigari Rithvik, George H. Moody Middle School

The effect of nectar Availability on Bee population Sustainability

Bees are considered to be effective pollinators that play a vital role in the maintenance of ecosystems and the improvement of agricultural production. In the last few decades, the number of bees has reduced due to environmental stress and inadequate food supplies. Nectar is considered to be a source of energy that is vital for the sustenance and proliferation of bee colonies. It is, therefore, of great importance to understand the relationship that nectar availability has to the sustainability of bee colonies. The research was conducted to establish the relationship that nectar availability has to the sustainability of bee colonies. In this research, a modified logistic growth model was used to model the simulation of the bee colonies. Initially, the bee colony was assumed to consist of 10,000 bees, and the carrying capacity was assumed to be 50,000 bees. In this experiment, nectar availability was assumed to be 100%, 75%, 50%, and 25% in order to determine the effect of reduced nectar availability to the sustainability of bee colonies. Ten trials were conducted to ascertain the reliability of this experiment. This experiment was also important in that it created a controlled environment that allowed for the comparison of the growth of the hive. The results revealed that there is a strong positive relationship between nectar and population sustainability. In this case, the population grew quickly and reached a plateau at full nectar, while the population grew at a slow rate and plateaued at lower population sizes at 75% nectar. At 50% nectar, the population plateaued at lower population sizes. At

25% nectar, colonies grew at a minimal rate and declined, revealing instability. This study confirms that more nectar is a key factor that ensures a larger and more stable population, while limited nectar hampers reproductive potential and increases the chances of population decline.

Ecology & Earth Sciences (MS EE)

First Place

Kirubaharan Vibha, George H. Moody Middle School

The Effect of Different Surface Types on The Amount of Fertilizer Runoff Entering a Water Body, and Eutrophication

Fertilizer runoff has been contaminating lakes and rivers for decades, contributing to eutrophication and the formation of harmful algal blooms. Excess nutrients entering water bodies can harm aquatic ecosystems and create health risks for humans through contaminated drinking water. Since surface type affects how water and fertilizer moves across land, understanding which surfaces produce the least runoff is important for reducing environmental and health impacts. The purpose of the experiment was to see how various surface types—concrete, grass, soil, and brick—affect fertilizer runoff. The hypothesis of the experiment was, if water was showered over concrete, then there would be more runoff than grass, soil, or brick. A setup was used in which 200 mL of tap water was poured over each surface using a plastic bottle with six holes to simulate rainfall. The surfaces were placed on an aluminum tray inclined at 20 degrees, allowing runoff to flow into a collection tray. Runoff was collected for thirty seconds and measured using a metric measuring cup. Each surface was tested ten times, and all constants, including water volume, tray size, incline angle, and timing, were kept the same. Grass produced the least amount of runoff, with a total of 694.97 mL across ten trials. Concrete and soil produced similar runoff amounts, totaling 946.35 mL and 961.13 mL. Brick resulted in the most runoff, with a total of 1434.31 mL, making the hypothesis incorrect. Overall, grass had the lowest mean runoff value, while brick showed the greatest amount of runoff. The results indicated that surface type significantly affects the amount of fertilizer runoff. Grass was the most effective surface at reducing runoff because of its ability to absorb and filter water, while brick, concrete, and soil had a larger amount of runoff enter the collection tray. These findings show that increasing grass surfaces may help reduce fertilizer runoff and eutrophication and could improve water quality.

Second Place

Kodari Saicharan, George H. Moody Middle School

The Effect of Erosion on Different Types of Ground Covers

This experiment was conducted to find the most effective type of ground cover for halting erosion. Erosion washes away the topsoil on land. Soil carries nutrients needed for crops to grow, and when soil gets carried away, the crops and plants die due to a lack of nutrients. Water was poured from varying heights and intensities. This is designed to simulate various rainfall types. This is to mimic the changes in rainfall intensity. I hypothesized that if we used the grass as a ground cover, then it would save the most soil. My reason for this hypothesis was that the grass roots would dig into the soil and wrap

around, holding it tightly like a claw holding a ball. The purpose of this experiment is to find a ground cover that can hold and cover up soil so it doesn't get eroded or washed away. Finding the solution to this global problem is important because it can help us solve the problems of farmland washing away, riverbanks widening, oceans getting polluted by soil, and flooding. The results held an interesting finding. The researcher aimed to determine which ground cover was most effective in preventing erosion, and in contrast to that, which was the most cost-effective. For both categories, grass won. Only letting an average of 1180 mg of soil go, Grass saved about 22.35 mg of soil per dollar spent. On the other hand, gravel did the opposite, doing worse on average than the unprotected soil and losing an average of 2722 mg of soil. Gravel lost 0.05 mg per dollar spent. In conclusion, this experiment tests which types of ground cover are most effective at preventing erosion. This can help fuel different experiments on pairing ground covers and soil types to create the most erosion-resistant ground types ever.

Third Place

Muhammad Daniyal Ijaz, George H. Moody Middle School

The effect of Ultraviolet light on biodegradable Polylactic Acid plastics and conventional Polyethylene plastic

Every year thousands of pounds of plastics are thrown into landfills where they take hundreds of years to break down. Ultraviolet light may be able to degrade and destroy the plastics earlier, preventing environmental harm. The hypothesis of the experiment was "If biodegradable plastics and conventional plastics like polyethylene are placed under UV light for a long period of time, then the biodegradable plastics will show more visible changes such as breaking or fading in color, than the regular plastics." Before the experiment began a cardboard box covered inside-out with tinfoil was constructed. Then 4 pieces of Polylactic acid plastic and Polyethylene plastic were placed inside. A UV light was mounted on the ceiling of the lid and faced the plastics. For 4 weeks the plastics were under UV light, being taken out one by one after each week interval. The purpose of the experiment was to see how PLA and PE plastics reacted to UV degradation. UV light accelerates the degradation of both materials, with biodegradable plastics showing more rapid visible changes and structural breakdown than conventional plastics. While both materials degrade under UV light, biodegradable PLA experiences rapid structural failure and weight loss, whereas conventional polyethylene remains flexible and largely intact.

Honorable Mention

Badodariya Aarya, George H. Moody Middle School

The Effect of Various Water Pollutants on the Speed at which Water is Entirely Polluted.

Water pollution has been a pending issue in the world environment for multiple decades now and has been spreading throughout our natural bodies of water at a rapid pace. The growing industries and farmland only cause this issue to be in more dire need of a solution. Which was done through a carefully executed experiment by the researchers. The procedure the researchers took when conducting this experiment consisted of preparing all materials and environments in which the experiment took place. After doing this, the experiment was conducted, and the data was recorded to be analyzed by the researchers. What incentivized the researchers to conduct this experiment was that many don't know the dangerous rate at which water pollution is dispersing through our

waterways. The researchers wanted to make this clear to the public, hoping to encourage them to take the necessary action. The results of this experiment consisted of the four levels of IV and the time each one took to disperse throughout the water as if in a natural environment. Bleach, being the first level of IV tested dispersed at an average rate of 3.32.1 seconds, followed by gasoline (vegetable oil combined with rubbing alcohol), which had an average dispersal rate of 0:11.1 seconds. Sunscreen had a dispersal rate of 0:40.3 seconds, and the last level of IV was detergent with a dispersal rate of 0. These results were quite shocking to the researchers, as their initial hypothesis stated, " If bleach within cleaning supplies is put into a container of water, then it will disperse the fastest through water." Ultimately, this experiment not only helped the researchers collect accurate data on the dispersal of water pollutants, but it also created awareness for this dire issue at hand that needs to have action taken upon it.

Engineering & Technology (MS ET)

First Place

Atulasima Advaith, George H. Moody Middle School

Integrating Piezoelectrics into Shoewear for Safe and Accessible Geolocation

Piezoelectrics are crystals that possess a unique property, which is to produce a charge when mechanical stress is applied to them. Stress and strain displace the center of the positive charge with respect to the center of the negative charge. (APC International, n.d.). This produces an electric field inside the material called polarization, resulting in charge forming at the electrodes. Conversely, applying an external electric field (voltage) to the material produces a displacement or change in shape. This material has found applications in fields such as medicine, for example, producing and sensing ultrasound waves for imaging. (Cafarelliet al.,2021). The aim of this study is to show a proof of concept that energy can be stored in a capacitor charged by piezos and potentially transformed. This understanding will help establish if sufficient energy can be harvested by a piezoelectric material placed in a person's shoe to transmit a geolocation signal to find a lost person. The hypothesis is that more piezos will result in a higher voltage being produced and more energy being transferred to an external capacitor. To test this hypothesis, different piezoelectric samples (multiple samples of single disks two disks, and 4 disks) were attached to a shoe and the voltage measured by connecting the piezoelectric to an oscilloscope, both directly and with an external capacitor added. The results showed that with a bridge rectifier and a power management circuit, you could potentially harvest enough energy to transmit someone's geolocation.

Second Place

Ahmad Hazeem, Louise Benton Middle School

The Effect of Temperature on the Elasticity of Silicone Polymers

Silicone is a polymer with many different uses and forms, as it is extremely strong and is used in many different inventions. The objective of this project was to test the strength of silicone polymers at different temperatures. Rectangular sheets of silicone were exposed to different temperatures and their elasticity was tested. This was done by using a spring scale and using a ruler to measure the stretch. Based on the data acquired,

warmer polymers generally have more elasticity, likely due to the molecules' vibration. The experiment concluded, based on the evidence collected, that silicone is more flexible under higher temperatures. despite other studies contradicting this claim. This is mostly because the silicone was tested in extremely different environments in the two experiments. Limitations include human error leading to inaccurate measurements and gaps in experimental testing. It is suggested that future studies use wider temperature ranges, differently sized pieces, longer exposure, and compare different materials with each other to find the best building material for certain products.

Third Place

Siddharth Rajan, George H. Moody Middle School

The Effect of Data Processing on Release of Heat on Computers and How to Counteract the Heat

With the rise of AI, thousands of data centers have been built around the world. But have people thought about the environmental damage these data centers cause and more importantly, how to fix it? The researcher wanted to find the best possible solution that could help reduce the amount of energy and water used. The researcher's experiment was The Effect of Data Processing on Release of Heat on Computers and How to Counteract the Heat. His main hypothesis was that if more efficient code is used, then the computers won't heat up as much. In order to conduct this experiment, the researcher used a single computer and multiple computing algorithms to size the experiment down to something that can be accomplished using the available resources. The researcher started by writing an algorithm which would simulate different levels of code efficiency on various levels of data processing while measuring CPU heat in each trial. He ran this code twelve times per combination of data size and algorithm efficiency and averaged out all twelve heat measurements received from each trial. The researcher noticed that there was an average of a 3-5 Celsius increase in CPU temperature between each level of code efficiency as code efficiency deteriorates. The results of the most extreme trial showed that using the extremely inefficient code and the largest data size resulted in an average of 70 degrees CPU temperature. In the trial using the most efficient code, the researcher's results displayed 56 degrees CPU temperature. In the end, the researchers' results proved the researcher's hypothesis but with some boundaries and uncertainty. The researcher's hypothesis was only proven correct when processing the least and most amount of data. In the end, the results showed that code efficiency only generates noticeable changes when working with very large data sizes.

Honorable Mention

Shah Aashvi, George H. Moody Middle School

The Effect of Different Surface Appearance on Heat Absorption

The researcher chose to conduct this experiment to study the effect heat absorption has on different surface appearances and materials. This project could help find solutions to the urban heat island effect, which is where cities become hotter than surrounding areas because of the large number of heat absorbing surfaces such as rooftops and pavement (US EPA, 2014), and also find ways to conserve energy, as non-renewable energy sources have been overused quite a lot. The scientist had predicted that the darker and less reflective materials would attract and absorb the most heat from a heat lamp. The

researcher exposed heat to six types of materials for three hours. These materials include wood, wood with gold spray paint, brick, brick with gold spray paint, aluminum foil, and aluminum foil with gold spray paint. The materials were then measured by an IR temperature, which calculated how much heat each material absorbed. After the project was conducted, the scientist observed that aluminum foil with spray paint ended up absorbing the most amount of heat, considering that the average for all five trials was 248.94 degrees Fahrenheit, although it had the most reflective surface. The material that absorbed the least amount of heat was wood without paint, which came to an average of 112.94 degrees Fahrenheit. After observing the collected data, the researcher learned that materials which were more wrinkled, tended to trap more heat, which is a big detail and discovery which answered the researcher's hypothesis. In closing, after the researcher conducted their experiment, analyzing and observing the hidden details which brought all the answers, can help find the resolutions for problems such as the urban heat island effect, and the overuse of non-renewable energy sources which are still thriving today.

Honorable Mention

Shivkumar Taran, George H. Moody Middle School

The Effect of Different Launch Forces (Newtons) on a Drone's Flight Time

The experimenter wondered how varying launch forces would affect the flight time of a glider-style drone. Although drones are typically manually launched, this investigation examined the effects of launching the drone with a slingshot to apply measured amounts of force. The hypothesis stated that if the highest force (40 N) were applied, the drone would achieve the longest flight time. The independent variable was the amount of launch force applied (10 N, 20 N, 30 N, and 40 N). The dependent variable was the flight time of the drone, measured in seconds. The experimenter assembled the glider-style drone and conducted the trials in a long indoor hallway to maintain a controlled environment. Ten trials were performed for each force level, and the flight times were recorded and organized in a data table. The results indicated that greater applied force increased the drone's time aloft, supporting the hypothesis. This experiment demonstrated a direct relationship between launch force and flight duration. Future research could investigate additional force levels or examine how aerodynamic factors such as lift and drag influence flight performance.

Honorable Mention

Tetala, Akshaj, George H. Moody Middle School

The Effect of Cooling Methods on Solar Panel Power Output

Overheating reduced solar panels' electricity output. The experimenter aimed to determine how effective different cooling methods were in improving the performance of solar panels. The experiment was conducted to determine the cooling method used, which would have enhanced the panels' performance. The experiment had the hypothesis of finding out whether the solar panel without cooling would produce more power in ten minutes than the panels with fan cooling, mist cooling, and ice pack cooling. For the experiment, the solar panel was placed 20 cm below the heat lamp and angled at 63 degrees. There were 4 different methods that were used in the experiment. The first method has the panel without cooling. The other three methods had a panel cooled by some form of cooling. The experiment was carried out 10 times for each of the methods.

Each experiment took ten minutes. The voltage and the current were measured by the use of a digital multimeter. The power produced by panels was then calculated, and the average was determined for each method. The control panel produced the least. Its mean wattage was 0.294W. Fan cooling had a higher mean output of 0.350W. Mist cooling increased the mean output to 0.384W. Ice pack cooling produced the highest mean output at 0.452W. Ice pack cooling showed the largest improvement. The control showed the smallest output. The original hypothesis wasn't supported. Cooling increased power output. Cooling methods affected solar panel efficiency. Ice pack cooling increased power most, mist and fan less. Cooler panels moved electrons efficiently, producing more electricity. Results matched studies showing lower temperatures improved performance. Proper cooling increased energy output in heat.

Human Behavior (HB)

First Place

Strickland Lydia, Sabot at Stony Point

The Effect of Branding on Food Preference

The purpose of this study was to determine whether branding affects food preference. To conduct this experiment, two brands of spiced rolled tortilla chips were tested: Takis® and Trader Joe's® Chili Lime Flavored Rolled Corn Tortilla Chips®. Participants were asked to eat Takis® out of two white bowls and pick which bowl was their favorite. They were then asked to eat Takis® out of a Takis® brand bag and a Trader Joe's® brand bag and pick which bag was their favorite. The hypothesis was that familiar branding would increase the likability of a product. The results showed that 72.72% of participants preferred the Takis® from the Trader Joe's® brand bag over the Takis® from the Takis® brand bag. This showed the participants were affected by more than just the taste of the product. This supported the hypothesis because there is a Trader Joe's® near the school where this study was performed and many participants were likely familiar with the Trader Joe's® brand.

Second Place

Westlake Griffin, Sabot at Stony Point

The Effect of the Length of Meditation Session on Heart Rate

This experiment found the effect of the length of a meditation session on heart rate. This study used mindfulness meditation. Mindfulness meditation involves sitting comfortably with your feet on the floor and your eyes closed. While meditating, participants held a heart rate monitor in each hand, which recorded their BPM over the ten-minute session. The results showed that there was a slight decrease overall in heart rate between the start and the 5-minute mark. However, heart rates tended to rise slightly between the 5-minute mark and the 10-minute mark. Although my original hypothesis was not supported, the results were interesting. For example, the heart rates became more consistent, with fewer highs and lows from minute to minute, the longer the participants meditated.

Third Place
Ananya Ware, George H. Moody Middle School
Effect of Sugar on Student Memory

Sugar intake of adolescents has been a highly discussed topic, as it affects teenagers over many areas of development. The purpose of this experiment was to determine whether sugar intake affects a student's memory and recall skills. The hypothesis was that if a student consumes sugar, then their memory game score will decrease. To conduct this experiment, ten students, from grades five through seven were selected to consume four variables of sugar, starting with the control, zero grams, and ending with the maximum amount, nine grams. After consuming the sugar, students were asked to play a memory game and have their scores recorded. The results of this experiment did not match the hypothesis; there wasn't a significant difference between the memory game scores and henceforth proved the hypothesis wrong. These experiment results match those of other similarly conducted experiments, which show that there isn't a correlation between sugar consumption and memory.

Mathematics Patterns (MP)

First Place
Sudhireddy Srihaas, George H. Moody Middle School
Comparative Performance Analysis of Investment Strategies Using Controlled Historical Back testing

Financial markets are the driving force behind economic growth and the creation of wealth, but investors are presented with investment choices that differ in terms of complexity, risk, and return. The objective of this study was to compare the outcomes of passive and active investment strategies through historical back testing. It was hypothesized that passive investment strategies would generate greater cumulative returns than active strategies when applied to the same set of historical data. The data was gathered and interpreted through spreadsheet calculations for the U.S. market index from January 2021 to December 2023. Four investment strategies, also known as passive market-tracking(control), buy-and-hold, 12-month moving average strategy, and one-month momentum strategy, were applied equally. Analysis of the results shows that passive market tracking and buy and hold approaches generated the highest cumulative return of 20.3% and average monthly return of 0.52% with volatility of 5.2%, while the moving average and momentum approaches reduced the volatility to 3.6% and 3.1%, respectively, but generated lower cumulative returns of 14.8% and 12.1%, respectively. The results proved the hypothesis and showed that the steady market exposure generated higher overall growth, while the active approaches based on rules reduced risk but at the cost of return, thus proving the fundamental trade-off between risk and return in financial markets.

Microbiology (MS MB)

Dorothy Knowlton Award
First Place
Konatham Drithi, George H. Moody Middle School
The effect of varying salinity levels on Nannochloropsis phytoplankton's ability to produce dissolved oxygen and deposit it into a a controlled environment

This experiment was conducted to determine which salinity level results in the largest amount of dissolved oxygen (DO) produced from *Nannochloropsis* phytoplankton cultures. Phytoplankton in general, accounts for over 50% of the oxygen produced on Earth (NOAA, 2021), which makes the microscopic protists an important source of oxygen for both marine and terrestrial life. Even though phytoplankton is very important to the environment, research shows that 1% of phytoplankton biomass dies every year globally due to varying reasons, including climate change, and to a lesser extent, extreme and sudden salinity changes (Boyce et al., 2010). This experiment worked to understand how salinity affected DO production by phytoplankton. So, the experimenter put 30mL of *Nannochloropsis* phytoplankton into different salinity levels, which were 10ppt, 25ppt, 35ppt (control), 40ppt, and 55ppt of salinity, into jars, and measured dissolved oxygen levels over time, to report how much DO the phytoplankton produced over a 48-hour time span. The researcher hypothesized that, if the phytoplankton cultures are exposed to salinity levels over 35 ppt, then they will produce much less dissolved oxygen compared to the phytoplankton cultures that are exposed to lower levels of salinity. The researcher carried out the experiment, and found that on average, the control produced the most dissolved oxygen (0.35 mg/L), followed by 25ppt and 40ppt of salinity, respectively. They also found out that 55ppt of salinity produced the least amount of dissolved oxygen. This was due to the fact that these specific phytoplankton cultures were adapted to the average salinity level of the ocean, 35ppt, and when the salinity levels changed drastically beyond that adapted salinity window, the cell composition of phytoplankton was harmed, which caused the cells to die and when phytoplankton dies, they sink down into the ocean with the CO2 they already absorbed, which caused lower dissolved oxygen values (Lionard et al., 2005), in the experiment.

Second Place
Rodriguez Lorena, Sabot at Stony Point
How Effective are Different Hand Sanitizers?

This experiment was conducted to find out which hand sanitizer was most effective, Purell hand sanitizer or Germ-X hand sanitizer. To conduct this experiment both hand sanitizers were added to a small hole in an agar plate inoculated with E. coli K-12, and after 10 minutes the zone of inhibition (a ring around the area that the hand sanitizer affects), was measured in millimeters. The hypothesis was that Purell hand sanitizer would be more effective than Germ-X hand sanitizer because it contains more alcohol. The hypothesis was supported because the results showed that Purell hand sanitizer had larger zones of inhibition and the spread of the data was smaller showing that the Purell hand sanitizer was more effective and consistent than Germ-X hand sanitizer.

Third Place

Bhashyam, Siddha, George H. Moody Middle School

Effect of Fruit Type on Imitated Bacterial Transfer to a Powder Surface in a 5-Second Contact Period

Bacteria are among the most helpful, but also among the most lethal and dangerous, organisms on Earth. The purpose of the experiment was to inform people about how easily bacteria can travel across surfaces, using common items of food, such as fruits that most people consume regularly, which can harbor large populations of bacteria. The hypothesis tested that different fruits would transfer different amounts of bacteria after 5-second surface contact. To safely model bacterial transfer, commercially waxed apples, ripe bananas, strawberries, and oranges (peel intact) were cut into uniform ¾ inch cubes. Each piece was dropped from a height of 8 inches onto 50 grams of cornstarch (simulating bacteria) and left in contact with the powder for 5 seconds. Ten trials were performed for each fruit type (40 total trials). The amount of cornstarch transferred to the fruit surface was determined by subtracting the final mass of cornstarch from the initial 50 grams for each trial. Results showed that apples had the lowest average transfer (0.52 g), followed by strawberries (0.64 g) and bananas (0.69 g), while the oranges had the highest average transfer (0.89 g). These trends support the hypothesis that different fruit characteristics influence the amount of cornstarch that can be transferred from a surface. In conclusion, this model demonstrated that fruit type significantly affects the imitated bacterial transfer within a 5-second contact period, with moister and rougher fruits (such as oranges) transferring more powder. Even though the changes in mass were small, they still give useful information about how quickly contamination can happen. The experimenter's findings highlight the importance of proper food handling and sanitation practices and demonstrate that fruit characteristics are significant when determining the risk of cross-contamination.

Honorable Mention

Sharma Yashna, George H. Moody Middle School

The Effect of pH Level on Milk Fermentation Completion Process

Milk fermentation is the process of making yogurt and highly relies on pH level to determine its speed for results. This study was conducted to research potential methods to make milk fermenting faster in order to reduce time and effort. Since yogurt is produced in factories, it releases emissions into the atmosphere as it is in the process of producing yogurt. While yogurt making can be done from home, businesses produce it in environmentally harmful factories. With the information from this experiment, manufacturers can reduce not only the time in making yogurt but also the amount of emissions released into the environment as it creates the same amount of yogurt but in less time. This experiment was conducted by setting milk at different pH levels by adding lemon drops into samples to make the initial pH value more acidic. Then, to ferment it, the experimenter had to incubate all the samples until they reached the yogurt pH level which was 4.5. Every two hours, the pH level was checked for each level of IV and was recorded. The researcher found that the initial pH level of 6 was the fastest in completing the fermentation process compared to the other levels of IV since it had an average of 6.4 hours. The hypothesis for this experiment was: If the pH level is 6, then the milk will reach a pH level of 4.5 faster. It was clearly supported by the data collected from the experiment

since it was the fastest level of IV to reach a pH level of 4.5. Many other studies showed similar results to this experiment with milk fermenting to a pH level of 4.5 in a matter of around 6-8 hours (Nummer, 2002). This comparison shows that the results that this experiment provided was accurate and supported by other studies too.

Physical Science & Astronomy (MS PA)

First Place

Gayapaka Anish, George H. Moody Middle School

Effects of Different Water Conditions on Soccer Ball Performance

Soccer is frequently played in wet environments, which may affect equipment performance. This study examined how different water exposures influenced soccer ball mass and rebound height. The purpose of the experiment was to determine whether tap water, salt water, or dry conditions produced measurable differences in weight and bounce performance after three days of exposure. It was hypothesized that tap-water–exposed balls would show the greatest increase in mass and the lowest rebound height, salt-water–exposed balls would show moderate changes, and dry balls would maintain the highest performance. Nine identical-sized soccer balls were divided into three groups: tap water, salt water, and dry control. The experimental balls were submerged for three days, while the control balls were stored indoors. After exposure, each ball was weighed and dropped ten times from one meter to measure rebound height. The dry balls had the lowest mean mass (276.8 g) and the highest mean rebound height (0.52 m). The salt-water balls had a mean mass of 299.9 g and rebounded to an average of 0.44 m, while the tap-water balls had the highest mean mass (305.7 g) and rebounded to an average of 0.43 m. The results showed that water exposure increased mass and reduced bounce height. Overall, the data supported the hypothesis that moisture negatively affected soccer ball performance.

Second Place

Weinrich Dylan, Marstellar Middle School

Illuminating the IR Spectra: A Python-based Approach to Classifying Brown Dwarf Stars

This project's main purpose is to prove that photometric analysis can filter large datasets of candidates and reduce them to smaller sets of higher-confidence candidates of brown dwarf stars. ORANGE3 is an open-source datamining application that utilizes Python in a user-friendly UI. ORANGE3 is especially useful for this project as it gives a wide array of tools at disposal for data analysis and display. The focus of this project is on the T1 spectral type brown dwarfs, to narrow down the criteria, and prevent overly large datasets. Photometric data can be used to sort stars based on the magnitude of light. Wide-Field Infrared Survey Explorer (WISE) was used as the source for photometric data, due to the ease of use in the W1-W2 band. W1-W2 is the difference in the magnitudes of the W1 (3.4μm) and W2(4.6μm) wavelengths. W1-W2 was used due to the data being a single variable, providing manipulatable data, which could be compared against other values easily. This data was gathered by CDS Strasbourg's SIMBAD (for object identifier, and coordinate data), VizieR (for photometric data), and X-Match (to crossmatch SIMBAD and VizieR data). A data processing pipeline was used in the project, consisting of multiple systems to adequately format data for use, and then using filters to calibrate an "average"

upper and lower bound of confirmed brown dwarfs. The bounds are compared against the dataset of 1000 unconfirmed brown dwarfs (W1-W2 values) to see what matches up before creating a list of brown dwarfs that fit the bounds. A dataset of 1000 brown dwarf candidates were reduced to only 38 higher-confidence candidates utilizing these upper and lower bounds. Using spectroscopy, this smaller dataset can be confirmed as a brown dwarf using the lithium test. As this project is about photometry, spectroscopy was not used and was not readily available. The higher-confidence candidates were visually inspected using Aladin Sky Atlas to rule out deep red galaxies and other objects.

Third Place

Fischer Eli, Sabot at Stony Point

The Effect of PSI on the Accuracy of a Soccer Ball

The purpose of this experiment was to determine the optimal pressure, measured in pounds per square inch (PSI), for a soccer ball in terms of accuracy. The results showed that 11 PSI resulted in the most accurate shots overall. This finding aligns with industry standards for PSI. When testing, I found that lower PSI was harder to shoot, and 13 PSI was too high. The PSI needs to be very specific. 2 PSI over is too high, the ball being too hard. And then the 2 under is too low, with the ball being unpredictable and hard to shoot with good technique. In conclusion, 11 PSI was definitely the best and right on the sweet spot. My hypothesis was supported with the lowest PSI being the least accurate. This is because most times when I try kicking a flat soccer ball, it's harder to get good technique with it, and it would be more inaccurate.

Honorable Mention

Michael Hannah, George H. Moody Middle School

The Effect of Temperature on Magnet Strength

Everyday items like cell phones, headphones, and even credit cards have magnets in them. The motive of this experiment is to resolve the issue that there are many people that do not recycle items that can be recycled and most people just use a trash can. Then, what will happen is those recyclable materials would get mixed up with actual trash even though a good amount of it could get recycled. The researcher used four rubber coated and circle shaped neodymium magnets. It is one of the constants because all those magnets are the same size, shape, and brand. The four different temperatures that the magnets were tested at are 0℃, 21.1℃, 40.6℃, and 60 °C. The control group of this experiment was 21.2℃ because that is room temperature. Lastly, the researcher will examine the data and create a bar graph that represents the average magnet strength for each of the four trials. The average number of paper clips held in general was 21 paperclips. The results showed that as the temperature of the magnet increases, then the magnet strength or the number of paperclips picked up decreases which supports the researcher’s hypothesis. The Curie Weiss Law states that because of heat, ferromagnetic magnets lose their strong and permanent magnetism. The researcher’s experiment had results that were aligned with the Curie Weiss Law because as the magnet got hotter, its strength decreased. A recommendation to make this experiment better is to increase the number of trials done so that it can be made sure that the results are legitimate. In addition, there could also be further study about this topic by using a microscope to see how the

atoms in the magnet react to the heat. Lastly, what could also be studied is how fast the magnet loses strength based on the different temperatures.

Plant Science (MS PS)

First Place
Ahmad Sarmed, Louise Benton Middle School
The Effect of Salinity on the Catalase Activity of Hydrogen Peroxide-Stressed Potato Disks

This experiment investigated how high-salinity environments affect plant health by measuring catalase activity in potato tissue. Potatoes were chosen because they contain abundant catalase, an enzyme that protects plant cells by breaking down hydrogen peroxide. Stress factors such as drought, parasites, and salinity can overwhelm their protective system, leading to oxidative damage. In the experiment, potato disks were soaked in salt water with different salt concentrations and then placed in hydrogen peroxide. Catalase activity was measured by the height of oxygen bubbles produced in graduated cylinders. The results showed that higher salinity levels significantly reduced catalase activity, while lower salt concentrations allowed stronger enzyme performance. These findings suggest that plants in highly saline environments struggle to manage oxidative stress, highlighting the importance of considering salinity tolerance in agricultural practices.

Second Place
Devarajan Lakshman Dheepthaa, George H. Moody Middle School
The Impact of Plant Types on the Accuracy of AI-Based Disease Detection

Keeping plants healthy is very important because diseases can ruin crops and even kill the plants over time. Artificial intelligence (AI) is a powerful tool that can help identify these diseases early by using computer vision to look at pictures of leaves. The purpose of this project was to determine how the type of plant species - tomato, green bean, plum, or apple - affects the accuracy of an AI model's disease detection. The researcher made a hypothesis saying that the AI model would be most accurate with apple trees because they often have very clear and distinct leaf symptoms, like spots, that are easier for a computer to recognize. The researcher made the AI model using the Python programming language and the Flask framework on the Replit platform, and they used the Plant.id API to analyze the images. The researcher performed 40 trials total, testing 10 images for each plant type, and then compared the AI's diagnosis to known disease information from agricultural databases to see if it was correct. The results showed that the apple trees had the highest mean accuracy at 79.41%, followed by plum trees at 74.91% and tomato plants at 73.45%. Green bean plants had the lowest mean accuracy at 65.88%. The researcher's data supported their hypothesis because the AI performed best on plants that had the most distinct visual patterns and detected apple diseases the best. This project shows that AI can be a great tool for helping gardeners and farmers identify diseases quickly so they can save their plants, and we can have a sustainable earth.

Third Place

Das Sharanya, George H. Moody Middle School

The effect of Organic and Chemical fertilizers on the growth of Mint plants

Each year, millions of waterways are polluted, affecting the environment and human health. The main cause of this problem is agricultural runoff, which is when excess fertilizer flows into rivers or lakes making its way to bigger water ways. This experiment was conducted to determine if organic fertilizers have a better impact on the height of plants than chemical fertilizers. If coffee grounds are used as fertilizer on mint plants, then they will grow the tallest. The experiment contained two organic fertilizers, two chemical fertilizers, and one control group, which made a total of fifty plants. Once a week each plant was given one tablespoon of fertilizer and each plant received 4oz of water each day. All plants received a day and night cycle, have 12 hours of light, and 12 hours of no light. At the conclusion of the experiment, the hypothesis was supported, as the plants given coffee grounds grew the tallest. A possible source of error may have occurred as the plants given coffee grounds were closer to grow light. After analyzing the data that was collected for the experiment and researching other sets of data, it was found that for many other experiments that coffee grounds stunned the growth of plants. Liebig's Law of Minimum says that plant growth decreases when an essential nutrient is limited. The control group may have lacked an essential source of nutrients, as the average height of that group was the lowest compared to the other groups.

Honorable Mention

Manikanta Ritu, George H. Moody Middle School

The Effect of Soil Salinity on The Bioelectrical Conductivity in Tomato Plants

This research paper examines the effect of soil salinity on the bioelectrical conductivity in tomato plants. Many farmers are battling the issue with having high soil salinity. When there is lots of soil salinity present it can disrupt the tomato plants growth and negatively affect the plants systems. Lots of salinity levels can lead to an overwhelmed plant and can affect the capacity of which the plants can photosynthesize and negatively affect the plants amount of nutrient intake, which can impact the plants health and survival chances. As too much sodium builds up in the plant it becomes overwhelming and can end up destroying the plant's cell membranes. The purpose of this experiment is to see if different salt levels can change the bioelectrical conductivity of a tomato plant. The hypothesis of this experiment was that if there is a high level of salinity in the soil then the Bioelectrical conductivity of a plant will increase due to the overwhelmed sense of the plant from the excessive amount of sodium present in the soil. The different amounts of salt used in the experiment were .5 tsp of salt, 1tsp of salt, 1.5tsp of salt, and 2 tsp of salt. To obtain the results, plants were grown for 20 days and then on the 21st day the plants were divided into 5 groups, watered with the specified amount of salt for each group, and after an hour measured the soil resistance at the root of plants for their resistance. The results displayed that the hypothesis was supported and if a high level of soil salinity is present then there will be increased bioelectrical conductivity present in the plant. Ways to improve this experiment would be to prepare the amounts of salt water beforehand, so the watering time is around the same time for all the plants.

Hari Rishi, George H. Moody Middle School

The Effect of the Removal of External Light Cues on Plants' Circadian Rhythms

Plants have circadian rhythms, or internal clocks that regulate certain activities that the plant does, such as ion movements throughout the cells. These movements can create electric changes, or bioelectricity. And whenever a cycle is done, plants use light to reset the rhythm. The purpose of this experiment was to show that plants have a circadian rhythm, via bioelectric signals and leaf movements. This experiment hypothesized that if all external light cues were removed, then the plant would still show signs that it knows the relative time to do certain actions. This experiment was set up by having three *Fittonia albivenis,* otherwise known as nerve plants. One was in a black box, one always had a grow light on, and one had nothing attached to it and was set close to a window, to have a natural cycle. Cameras and an Arduino system with amplifiers were set up for the plants to create leaf movement time-lapses and detect bioelectricity. This experiment had 10 trials, and each trial was 72 hours long. The plants in full darkness ended up having similar signals to the control, although they were slightly off. The plants in full light ended up becoming more unstable the longer the trial lasted, with the signal changes becoming more dramatic and frequent, and leaf movements shifting towards the light source. The hypothesis was partially supported, as while the plants in darkness supported it, over time, the plants in full light became less and less stable. This supports the idea that too much artificial light could damage or reduce the effectiveness of a plant's circadian rhythm. Because light is meant to "reset" the circadian rhythm, too much could override it, interfering with other important plant functions like using photosystems. Understanding how artificial light can affect a plant's circadian rhythm could have implications for artificial plant growth environments.

Choudhary Reyansh, George H. Moody Middle School

The Effect of pH on Plants

Life on our planet is one that we take for granted, instead of cherishing, we trample our home up in flames. Acidification is purging ecosystems both underwater and across the world, many ecosystems cannot survive the decreasing pH, with calcium structures and the bodies of many organisms succumbing. Climate change and pollution ravage, raising global and oceanic temperatures, pumping carbon dioxide (CO2) into the atmosphere- of which our oceans absorb 30% (United Nations, 2024). Marine plant life and biodiversity are rapidly declining, causing fatal harm to the planet and the fragile balance of life on Earth- leading to the extinction of hundreds of species and even the deaths of thousands of humans a year, proving it to be a pushing problem for each individual who calls this planet home. This experiment was conducted to further examine how pollution and human-caused climate change correlates with the degrading of marine environments such as coral reefs and other areas of the marine biosphere. The experimenter hypothesized that a decrease in pH would reduce the plants' photosynthesis rate, metrics, and starch created. Although larger and more thorough research will be required to directly show a substantial variation in starch content. *Elodea densa*, which was chosen due to its versatility and ability to survive in many environments, were placed in separate tanks of different pH's, including the projected pH if emissions are not slowed, the neutral pH, the pH levels that were held constant for millions of years prior, and extremes, with their dissolved oxygen content (DO) and height are measured every 12 hours after

photosynthesis and respiration cycles. The results found that an *Elodea densa* exposed to a pH of 5.5, which is a projected pH if we do not stop our carbon emissions, would use more oxygen than it would produce, losing 0.0125 mg/L of DO every 12 hours.

Manikandan Sadana, George H. Moody Middle School
The Effect of Natural Pesticides on Plant Growth and Physical Appearance

Plants are the fundamental foundation of life on planet Earth, yet they are mostly forgotten about on health. Over the years, agricultural workers have done multiple procedures to maintain good looking plants. Pesticides as one of the best ways to maintain healthy- and good-looking plants however high concentrated chemical pesticides lead to disfiguration in level of greenness or chlorophyll and disrupt growth intake. This led to the experiment conducted titled The Effect of Natural Pesticides on Plant Growth and Physical Appearance. This experiment was conducted to see if natural pesticides can act as a better substitute to regular pesticides when compared to growth and physical appearance resulting in better plants. The main purpose was to see how efficient these natural solutions can be moving on in the further agricultural work industry and if it could be a better alternative when comparing it to the plats overall reaction to it.
The experiment was done by creating 3 natural pesticide solutions and comparing it with a regular pesticide. The 3 different natural pesticides which are the independent variables are chili, cinnamon, and neem. Mint plants were used to test the experiment on. The dependent variable was measuring the plant growth by leaf size and physical appearance by measuring its greenness level with a chart created by the experimenter. The control group has no pesticide, and the constants consist of plant pots used, spray bottles used to spray the pesticides, and the soil used. The plants received 10mL of water each day for 2 weeks and belonged in a sunlight area zone receiving sunlight every day. The experimenter's hypothesis was that if natural pesticides are used on plants, then it would result in less damaged mint plants. After conducting the experiment, it came to the conclusion that natural based pesticides worked better compared to the synthetic chemicals because the neem pesticides had the highest level of greenness and best growth.

High School Sections

Botany A (HS BOT-A)

First Place
Martin Zach, Central Virginia Governor's School for Science and Technology
The Effect of Auxin and Cytokinin on Variegated Reversion in Tradescantia Under Varying Light Conditions

Variegation, a highly desirable trait in horticulture, often reverts under non-ideal conditions. This study investigated whether the application of the hormones; auxin (Indole-3-Butyric Acid) and cytokinin (Kinetin) could slow the reversion of variegated-like pigment in *Tradescantia* leaves that were exposed to different light treatments. Sixty *Tradescantia* cuttings were placed under high and low light conditions with applied

hormone and control groups. Hormones were applied once at a concentration of 50 mg L^{-1} in 80% ethanol. Leaf images were collected across three timepoints (beginning, middle, and end) and analyzed to quantify purple and green pigment percentages. Two-way ANOVA tests were used to determine the effects of each hormone application, timepoint, and light treatment on the percentage of purple pigment. Hormone application did not significantly affect purple pigment under high light and low light, as p-values of .29 and .27 (alpha .05) were provided. There was no significant interaction between hormone application and the timepoint, with marginal significance ($.05 < p < .1$) under high light as a p-value of .07 was given. Light level showed a statistically significant effect across every grouping with a p-value of less than .01, with plants grown under high-light conditions displaying higher average percentages of purple pigmentation. The research hypothesis which stated that administration of Indole-3-Butyric Acid and Kinetin would slow the reversion of the variegated-like pigment in *Tradescantia* plants exposed to varying light conditions was not supported, as hormone application was insignificant, while light level played a significant role in the pigmentation of *Tradescantia* leaves.

Second Place

Salama Abdelrhman, Mills E. Godwin High School

The Effect of Various Household Greywaters on Raphanus sativus Growth

The experiment's purpose was to provide information on sustainable alternatives for freshwater, helping developing countries to grow crops without negative side effects. This study examines the impact of different types of household greywater on radish growth. Freshwater in developing countries is scarce, while greywater is available and can be used as an alternative, but some can also be harmful. It is hypothesized that cooking greywater will maximize growth by providing enough nutrients without negative effects seen with other types. The control is Tap water. The experiment used four 90 x 30-centimeter gardening containers, each filled with 7 liters of soil and watered with the designated type of Greywater. Twenty-five radish seeds were planted per container, watered daily, and exposed to sunlight daily. After six weeks, the data on growth was collected and analyzed through descriptive and inferential statistical methods. There were six t-tests calculated, all resulting in the critical value being less than the calculated. This means all of the data was significant. The mean of the Tap Water was the highest, but that is negligible because the experiment is trying to find the best alternative to tap water. This means that the second-highest mean is the best alternative, which is cooking water. Sink water is not a bad alternative either because it did not come far behind cooking water. However, Laundry Water came at a mean of Zero, meaning it should not be used. This experiment could be furthered by knowing if the intensity of the greywater affects crop yields.

Third Place

Belko Yehor, Long Samuel, Roanoke Valley Governor's School

A Study of the Allelopathic Effect of Polyphenols on the Germination of Medicago sativa and Lepidium sativum

Food is limited as world hunger persists. *Medicago sativa* (alfalfa) and *Lepidium sativum* (cress) are quality foods fed to common livestock. The hypothesis was that if a solution of tannins was used to water *L. sativum* and *M. sativa*, then the germination and growth will depend on the tannin concentration. Research on how tannins affect growth of

feed crops may enable farmers to control growth of these crops by inhibition and/or stimulation. More crops can support cattle which provides more food. A subclass of *polyphenols* is tannin, which is easy to get from tea, coffee, and plant waste but is under researched due to its complexity. This experiment used six concentrations of tannin: 0%, 0.01%, 0.1%, 1%, 10%, and 20%. Thirty-six seeds per concentration were used for each type of seed. Germination and radicle length data was taken every twenty-four hours for seventy-two hours. Germination and concentrations data was qualitative, so Chi-squared test was used for each twenty-four-hour period. The resultant p values for each twenty-four-hour period were: 0.981, 0.625, 0.064, 0.086, 0.061, therefore null hypothesis failed to be rejected. A One-Way ANOVA test was used to analyze the effect on radicle length. The null hypothesis was rejected with resultant p values being significantly under 0.05. The radicle length of *M. sativa* showed a 19.2% increase at 0.01% and 54.17% decrease at 1% concentration after seventy-two hours. The conclusion was that tannin needs more research to determine optimal concentration for stimulation and/or inhibition of germination to be used by farmers.

Honorable Mention
Basi Jaiveer, Mills E. Godwin High School
The Effect of Premature Darkness and Delayed Nightfall on Adaptive Nyctinastic Movement in Phaseolus vulgaris

Circadian clocks, which are endogenous rhythms used for synchronization to the light cycle, integrate environmental signals with internal cues to coordinate diverse physiological outputs so that they occur at the most appropriate time of day. However, little is known about the impact of exposure to specific offset light cycles on the speed of this entrainment in the common bean plant, a key agricultural crop. The initial aim was to understand the adjustment of the internal rhythm of plants to predict their behavior in severe climate change. Entrainment was determined by measuring the time it took for any leaf petiole to rise to 60 degrees after the onset of darkness. This process was repeated for five days after a 14-day growing and germination period. The control used was a normal light cycle relative to Richmond, VA, in the fall, with darkness occurring at 5:07 pm. The research hypothesis for this experiment was that plants subjected to a light cycle with darkness at 6:00 pm would entrain most effectively. Compared to day four, plants subjected to darkness at 4:15 on day 5 closed in, on average, 6 minutes later; plants with darkness at 4:30 on day 5 closed 3 minutes later, plants with darkness at 5:07 pm had a 1-minute difference, and plants with darkness at 6:00 pm closed 8 minutes earlier. The t-tests performed revealed that all of the data were significant. The research hypothesis was not supported. It is believed that the results were due to the natural phase response curves in circadian rhythms, which caused earlier times to have a more effective reaction while later times took longer to adapt. This research could lead to further experiments manipulating darkness on a finer scale to determine the specific phase-dependent sensitivity of the circadian clock.

Honorable Mention
Pantelic Marina, Mills E. Godwin High School
The Effect of Auxin and Cytokinin Ratio on Radish Growth

This study was conducted to determine the most suitable ratio of auxin to cytokinin in radish plants. The ongoing crisis of climate change and pollution causes produce to be harder to acquire, so the application of hormones for efficient growth could be beneficial to farmers and consumers of produce. It was hypothesized that out of three manipulated groups, one hormone each and one combined, the cytokinin group would allow for the greatest sprout length, indicating a more suitable vegetable. A control group of no added hormone was included to visualize the standard growth and use for statistical comparison. 25 seedlings were germinated for each stressed group, to which the hormone was added for the last month of growth with a total growing time of 1.5 months. The results concluded that the cytokinin group in fact had the largest centimeter sprout growth, supporting the research hypothesis. Despite this group visually being relatively close in growth to the control group, this level, along with the two others, were all statistically significant. The auxin and combined sprout groups had significantly less growth, and the most likely cause of this was either due to the de-rooting method of auxin powder application, or the IBA variant of auxin found in the powder being too potent for the specific plant. For future experimentation, the other variant of auxin, IAA should be tested for safer hormone application. Testing the other major hormones found in plants or using a different base plant would be beneficial as well.

Honorable Mention

Johnson Gavin, Central Virginia Governor's School for Science and Technology

To what extent do varying sound frequencies affect the overall growth of Brassica rapa?

The purpose of this study was to connect the overall growth of the *Brassica Rapa* plant to varying sound frequencies. This study was conducted to see if plants were at a disadvantage in growth in bigger, more populated areas due to the noise that these areas produce. The study was conducted at a local high school in the winter of 2025. A speaker was used to expose 10 plants per trial in an environmental chamber to selected sound frequencies of 0 Hz, 5000 Hz, and 10000 Hz. After their growth, the height and stem width (cm and mm, respectively) were taken. Results showed that the frequency the plants were exposed to negatively affected the height of the plant as this frequency was increased, with a p-value of <.01 with an alpha of .05. The 10000 Hz frequency had the worst average height, around 2 cm less than the control. Stem width showed no significant effect based on the frequency, with a p-value of .13 with an alpha of .05. A one-way ANOVA test was used to analyze the results. These results partially supported the hypothesis that the plant's overall growth would be negatively affected as the frequencies were raised. This research can be used to help plants grow better in city environments and can be applied to limiting noise near and around where plants are growing.

Crosby Colleen, Central Virginia Governor's School for Science and Technology

The Effect of Different Colored Growth Lights on the Stem Height of Capsicum annuum

The purpose of this experiment was to research whether the color of LED grow lights influences stem height in bell-pepper (*Capsicum annuum*) plants. Forty healthy seedlings were randomly assigned to four treatment groups (n = 10 per group) and exposed to white (control), orange, purple, and blue 24W LED strips for six hours daily over a four-week period. Plant height was measured weekly with a ruler to the nearest millimeter, and mean height increase (cm) was calculated for each group. Descriptive statistics indicated mean

increases of .3 cm for white, .2 cm for orange, .2 cm for purple, and .1 cm for blue light. A one-way ANOVA was performed ($\alpha = .05$) and yielded a significant effect of light color on stem growth ($p = .04$). Post-hoc Tukey tests identified a significant difference only between white and orange treatments ($p = .03$). Although all other pairwise comparisons were non-significant, the results support the alternate hypothesis that light color affects bell-pepper growth, with white light producing the greatest stem-height increase. These findings suggest that white lighting may be most effective for indoor pepper cultivation.

Alamirew Soliana, Mills E. Godwin High School

The Effect of Coffee Grounds on Plant Development

The purpose of this study was to determine whether spent coffee grounds (SCG) function as a beneficial soil amendment or a harmful environmental disruptor regarding plant development and pollinator behavior. As coffee remains the world's third most consumed beverage, the resulting waste often leaches caffeine into waterways, causing physiological stress to aquatic life. Finding sustainable ways to repurpose SCG in gardening could diminish this pollution while improving urban biodiversity. It was hypothesized that low concentrations of SCG would improve plant health and increase pollinator visitation, whereas high concentrations would inhibit growth and disrupt pollinator patterns due to caffeine toxicity. The experiment utilized 100 Aster plants divided into four levels of the Independent Variable: 0g (Control), 5g, 10g, and 15g SCG by mass. The 0g control group was essential to isolate the specific effects of caffeine and nitrogen from natural growth variances. In a controlled greenhouse environment, vegetative health (height and leaf color) was measured weekly for 4 weeks. Inferential statistical analysis revealed a significant "Goldilocks effect": the 10g treatment group showed optimized growth with the best chlorophyll dense leaves. Conversely, the 15g group exhibited stunted growth and deficient health indicators. These results suggest that while nitrogen provides initial benefits, excessive caffeine acts as a potent allelochemical. In conclusion, SCG is an effective eco-friendly fertilizer only at low concentrations, exceeding these levels renders the waste phytotoxic, necessitating precise application to protect botanical health and local ecosystems.

Limon Crecerelle, Clover Hill High School

The Effect of Applying Varying Amounts of Citrus Peel to the Base of Epipremnum aureum on Epipremnum aureum

As a major waste product of fruit-processing industries, citrus peels make up a large portion of pollution caused by food waste. The objective of this experiment was to test whether repurposed leftover orange peels could be applied as a growth boosting fertilizer agent in order to determine the successfulness of improving *E. aureum* growth rate through the application of varying amounts of ground dried orange peel. Also, the peels were used to determine if using citrus peels as a growth-boosting agent would be an efficient means to cut back on pollution from fruit-processing industries. The independent variables in this experiment included the varying amounts of citrus peel, in grams, applied to the base of *Epipremnum aureum* (*E. aureum*) plants, also known as Golden Pothos. The dependent variable was the growth rate, measured by calculating the differences in height per week for each individual plant, which were then converted to percentages. The experimental hypothesis was rejected due to ANOVA test results, which determined that all levels of

citrus peel application were insignificant. Results were as follows: Group 1: P-value = 0.99551; Group 2: P-value = 0.74262; Group 3: P-value = 0.86886; Group 4: P-value = 0.14972; Group 5: P-value = 0.448; and Group 6: P-value = 0.62648. The experiment was conducted over 8 weeks, throughout which citrus peel was applied in varying amounts to the bases of *E. aureum*. Measurements were taken in cm every 7 days in order to monitor the growth rates of each individual plant, which were later averaged out as percentages and used to determine the average percentage of growth rate per level.

Burukunte Aarush, Mills E. Godwin High School

The Effect of Caffeine Concentrations on Phaseolus vulgaris Growth

The purpose of this study was to quantify the effect of varying caffeine concentrations on the vertical growth of *Phaseolus vulgaris* (common bean) to determine whether caffeine acts as a stimulant or inhibitor. Although spent coffee grounds are popular as organic fertilizer, caffeine's allelopathic properties can suppress growth. It was hypothesized that as caffeine concentration increases, the growth rate of bean plants will increase due to metabolic stimulation and nitrogen content. A randomized block design was utilized with a control group (distilled water) and three experimental groups receiving weak (1:100), moderate (1:50), and strong (1:25) coffee decoctions. Over 40 days, the height of 25 plants per group was measured daily. Results indicated a non-linear, hormetic dose-response. The weak concentration achieved the highest mean height (53.99 cm) compared to the control (50.16 cm). However, moderate and strong groups demonstrated severe stunting (37.03 cm and 29.05 cm). A t-test confirmed all differences were statistically significant ($p < 0.01$). The hypothesis was rejected; high concentrations proved phytotoxic, while dilute concentrations functioned as a bio stimulant, suggesting coffee waste requires precise regulation when used as a soil amendment.

Mishra Anshuman, Mills E. Godwin High School

The Effect of Temperature in Electrical Signals on Phaseolus vulgaris

The purpose of this study was to investigate how temperature variation affects the electrical signal activity in *Phaseolus vulgaris* (common bean plants). Plants rely on electrical signals to respond to environmental changes and understanding how temperature influences these signals can help scientists better understand plant stress responses, agriculture efficiency, and climate change impacts on crops. As global temperatures continue to fluctuate, studying plant electrical behavior may contribute to improving crop resilience and food security. It was hypothesized that if the temperature surrounding *Phaseolus vulgaris* increases, then the measured electrical signals (millivolts) will also change because temperature affects ion movement and cellular activity within plant tissues. A control group was included in this experiment to ensure accurate results. The control consisted of a “no contact” condition, allowing baseline electrical readings to be compared with temperature-treated plants. This helped determine whether changes in electrical signals were caused by temperature rather than background electrical noise. The procedure involved measuring electrical signals from *Phaseolus vulgaris* using a DC digital multimeter at five conditions: 10°C, 22°C, 35°C, 45°C, and a no-contact control. Each temperature condition included 25 trials to improve reliability and reduce random error. Electrical signals were recorded and averaged for analysis. The results showed noticeable variation in millivolt readings across different temperatures, indicating that temperature

does influence electrical activity in the plant. Higher temperatures generally produced greater fluctuations in electrical signals compared to lower temperatures and the control group.

Botany B (HS BOT-B)

Virginia Academy of Science Botany Award
First Place

Obeng Lauren, Seyefe Ruth, Ahmad Sajeela, Governor's School @ Innovation Park

Antioxidant-Mediated Recovery of Mitochondrial Function and Cell Viability in Hydrogen Peroxide-Stressed Nicotiana tabacum Callus Tissue

Abiotic stress-induced overproduction of reactive oxygen species reduces mitochondrial health, ultimately leading to issues such as reduced crop productivity. In the present study, the ability of antioxidants resveratrol, curcumin, and epigallocatechin gallate to counteract hydrogen peroxide-induced oxidative stress in Nicotiana tabacum callus tissue was evaluated. Callus tissues were treated with 0.5 mM H_2O_2 to induce oxidative stress, followed by treatment with 50 μM antioxidants. Outcomes were measured through the TTC assay for mitochondrial health, the DCFDA assay for the abundance of reactive oxygen species, and the CAT catalase activity assay. Each of the antioxidant treatments resulted in no significant changes compared to the controls in mitochondrial function or ROS accumulation. No significant differences were found in the reversal of oxidative stress or antioxidant activity when comparing the results of the three antioxidants. These results suggest that exogenous antioxidants may not significantly ameliorate oxidative stress or trigger mitochondrial recovery in plant cells exposed to abiotic stress. The results should not be taken as conclusive evidence; instead, experimental limitations suggest certain improvements needed to better test these antioxidants. All in all, these findings support that further research is needed regarding the use of exogenous antioxidants to reduce oxidative damage and promote mitochondrial recovery in plant tissue under abiotic stress. Further research should focus on specific crop species, refine antioxidant concentrations, and evaluate realistic timelines and costs to facilitate practical use in agriculture, while avoiding the limitations of this study such as small sample size.

Second Place

Nair Niharika, Mills E. Godwin High School

The Effect of Rhizobium Inoculation on Bean Plant Growth in Saline-Stressed Soil

This research aimed to determine whether *Rhizobium* inoculation would act effectively in assisting bean plant growth under saline stress. *Rhizobium* is known to improve crop yields in regular soil, and this research could potentially enable agriculture in regions with poor soil quality. Regular bean seeds were either inoculated or left as it is and planted in either regular soil or saline-stressed soil. The seeds were allowed to grow into plants for 33 days, and then their height was measured, as well as root length and plant weight for additional data. The control that was used in the experiment was a

set of regular, uninoculated bean seeds in saline soil. A hypothesis was formulated that inoculation using *Rhizobium* would significantly assist with plant growth occurring under soil with saline stress. The results revealed that seeds under *Rhizobium* inoculation grew, on average, 9.44 cm more than regular seeds when in saline-stressed soil. A t-test was conducted on the data, and it revealed that the data was significant for inoculated seeds in saline soil versus regular seeds in saline soil (control). Therefore, the results did support the research hypothesis. According to various studies, it is believed that the results are due to nitrogen-fixation, Indole-3-Acetic Acid (IAA), and 1-aminocyclopropane-1-carboxylate deaminase (ACC deaminase) mechanisms. This research could lead to further studies that investigate specific strains of *Rhizobium* to identify the most effective ones.

Third Place

Friedman Gabriel, Central Virginia Governor's School for Science and Technology

Comparing the Effects of Different Fertilizers on Glycine max Grown in Lunar Regolith

The purpose of this study was to identify the fertilizer yielding the healthiest plants when used with lunar soil. *Glycine max* was the plant used in this study. The emergence percentages, heights, leaf masses, and photosynthetic activity were measured within the control group, having no fertilizer, and the three experimental groups, having a chemical fertilizer, manure, and compost. The results of this study showed that organic fertilizers performed the best. All three experimental groups had higher emergence rates than the control's 25%. The manure group had 29.2%, and the other two had 37.5%. A similar trend was observed with leaf masses, with the manure and compost groups having nearly double the average leaf mass of the other two groups. These two measurements could not be statistically tested, and height, in which the organic fertilizers again were greater, was not found by an ANOVA to be statistically significant (alpha = .05, p-value = .16). Photosynthetic rate, measured by the floating leaf disk technique, was found to be statistically significant by an ANOVA (alpha = .05, p-value < .01). The control group averaged 732s to float, while chemical fertilizer averaged 626s, manure averaged 481s, and compost averaged 405s. These results partially supported the research hypothesis that fertilizing lunar soil with manure would yield the healthiest plants. The use of organic fertilizers on the moon also allows for self-sustaining agriculture, as waste from one round of crops could fertilize the next. Enabling off-world agriculture in this way will support space exploration and enable longer-duration missions.

Honorable Mention

Howard Elaina, Central Virginia Governor's School for Science and Technology

The Allelopathic Tendencies of Wheat and Ryegrass

The purpose of this experiment was to determine if the defensive biochemicals, specifically allelochemicals, in wheat and ryegrass would negatively affect each other's growth rates. There were three different groups tested, in which ryegrass and wheat were grown at varying distances from each other. The first group had a distance of 2 cm, the second had a distance of 3.5 cm, and the third had a distance of 5 cm. The height of the plants in each group was measured weekly using a ruler and was analyzed at the end of the two-week study using a 2-way-ANOVA. Using an alpha value of .05,

resulting p-values were X (spacing) = 0.31, Z (plant type) = 0.20, and X-Z (interaction) = 0.97. The results showed no significant differences in growth between groups, and that the distances between the plants did not cause any significant change in their height. The hypothesis that growth rates would differ based on spacing was not supported. These findings suggest that allelochemicals between wheat and ryegrass did not significantly influence growth at the tested distances, indicating that other factors may play a greater role in determining plant height under these conditions. These results indicate that allelochemical interactions between wheat and ryegrass are unlikely to significantly affect growth at close distances, suggesting that other environmental factors may have a larger influence on plant performance in agricultural systems.

Honorable Mention

Hartso-Smith Joshua, Chesapeake Bay Governor's School

Comparing the Growth rate Between Aquaponics, Hydroponics, and Composting in a Home Environment

The biggest problem every country faces is having hundreds if not thousands of people that don't know where their next meal is coming from. Therefore, scientists and farmers have worked together to create a few new innovative ways that can help world hunger that were studied in this experiment. This study compared the growth of bibbed lettuce and cherry tomato plants in three systems, hydroponics, aquaponics, and composting. After the experiment was concluded, each set of data for the bibbed lettuce and cherry tomatoes had an ANOVA single factor test run on them to get stats for the plants. The results show that over the 70-day growth period, hydroponics had the highest average growth rate followed by aquaponics and then compost for both the bibbed lettuce and cherry tomatoes. The results for bibbed lettuce had a p-value of 8.83 E-10, and cherry tomatoes had a p-value of 8.61 E-6 meaning that both sets are significant. For the percent germinated and alive throughout the study the bibbed lettuce, showed hydroponics had the best percent alive followed by aquaponics, and then composting. For cherry tomatoes, both hydroponics and aquaponics had the same percent alive then following it was compost. In this study the hydroponics was able to have better plant growth in both the cherry tomatoes and bibbed lettuce. The benefit of all three of these methods is that they can produce food in small-scale or large-scale systems and are more environmentally friendly than common agriculture methods.

Honorable Mention

Polavarapu Sahasra, Mills E. Godwin High School

The Effect of Various Spices on Radish Seed Germination Rates

Recently farmers had adapted to more organic farming methods compared to conventional pesticides and fertilizers. Rather than chemicals, the naturally derived spices served as a true organic farming method. The purpose of the experiment was to determine the effects of various spices on Radish seed germination rates. The spices clove, ginger, turmeric, cinnamon was each mixed with 100 ml of water before a coffee filter was placed inside each solution. Twenty-five seeds were then placed on top of the coffee filters which were then placed into their corresponding petri dish. The control of plain tap water was used in the experiment. It was hypothesized that the cinnamon

solution would result in the highest radish seed germination rates. The seed germination rates were then measured based on a scale of whether the seeds had germinated or not. The results revealed that the turmeric solution germinated the most seeds as all twenty-five seeds germinated. Chi squares were conducted for all the IV levels, proving all tests and data to be significant. The results indicated the research hypothesis was not supported. Due to the harsher conditions in which the seeds were placed into, the spices needed to contain proper antibacterial and antifungal properties such as turmeric's curcumin. Many of the spices may have been too strong for the seeds to tolerate as the clove solution had strong antimicrobial properties. The experiment could have led to further studies of spice solutions on plant growth rather than seed germination.

Oden Paige, Mills E. Godwin High School
The Effect of Organic Stimulants on Plant Health

Stimulants such as coffee, tea and yerba mate have many positive attributes that could potentially enhance plant health. Organic stimulants are often suggested as healthier alternatives to hazardous fertilizers, but this study tested whether common stimulants actually improve or hinder plant health. The purpose of this study was to investigate the effects of various organic stimulants on plants to determine which stimulants enhanced or hindered plant health in hopes of finding an alternative to fertilizers that is natural and causes no harm to the environment. It was hypothesized that if coffee contains beneficial antioxidants that are useful to plants, then the plants receiving coffee will be healthy. Diluted solutions of the stimulants were developed, with water acting as the control to compare the health of the plants. Twenty-five trials per level were conducted with four levels, plants were grown over the course of two weeks, and the stimulant was added at the beginning of the third week. Plant health mode was recorded after the third week. Chi-square tests showed at $\alpha = 0.05$ that all independent variables were statistically significant. These results suggested that stimulants hinder plant growth and therefore have a negative effect. Future studies could research different approaches to giving stimulant concentrations, stimulant amounts and using stimulant waste such as used coffee grounds.

Jayakanthan Sravan, Mills E. Godwin High School
The Effect of Anti-frost Solutions on Mass Loss of Spinach

The purpose of this study was to determine if anti-frost solutions derived from Brassicaceae extracts (mustard, kale, and radish) could reduce freeze-thaw damage in spinach leaves. Frost damage is a critical agricultural challenge where ice crystals puncture cell membranes, leading to fluid leakage and mass loss. Finding natural, plant-based antifrost solutions is essential for small-scale farmers who require low-cost, sustainable alternatives to expensive mechanical frost-prevention systems to ensure improved crop resilience against sudden temperature drops. It was hypothesized that if spinach leaves were treated with these extracts, they would lose less mass than those treated with water, with mustard and kale predicted to be the most effective due to high glucosinolate and antioxidant concentrations. The experimental design utilized a control group of leaves soaked in water to establish a baseline for natural cellular rupture and fluid loss in the absence of protective solutes. Twenty-five trials were conducted per

group. Spinach leaves were soaked in their respective solutions, subjected to a freeze-thaw cycle, and measured for mass loss in grams. Results of the t-tests indicated that all three treatments significantly reduced mass loss compared to the control ($P < 0.05$). Mustard greens showed the highest significance ($T = 4.85 > 2.01$), followed by radish leaf ($T = 4.39 > 2.01$) and kale ($T = 1.70 < 2.01$). The conclusion is that the phytochemicals in Brassicaceae extracts effectively stabilize plant cell membranes against freeze-induced injury. The hypothesis was fully supported, demonstrating that these natural extracts serve as accessible, environmentally friendly frost-protection agents.

Almond Donald, Mills E. Godwin High School

The Effect of Magnetic Fields on the Germination and Growth of Phaseolus Vulgaris

The purpose of this study was to determine the effects of varying magnetic field strengths on the germination and early growth of pinto beans (*Phaseolus vulgaris*). This research is relevant because increasing use of electrical devices has raised environmental magnetic field exposure, which may influence agricultural productivity. It was hypothesized that increasing magnetic field strength would reduce both germination rate and plant growth. Pinto bean seeds were exposed to magnetic field strengths of 0 μT (control), 15 μT, 30 μT, and 60 μT for a period of 14 days. All plants were grown under identical conditions and watered consistently. Germination was measured by counting sprouted seeds, and growth was measured as seedling height in centimeters. Descriptive statistics were calculated, and inferential statistics, including t-tests and chi-square tests, were performed at a significance level of $\alpha=0.05$. Results showed that magnetic field strengths of 15 μT and 60 μT increased both germination rate and plant growth compared to the control, while 30 μT reduced both variables. Most statistical comparisons were significant ($p < 0.05$), though some were not. The hypothesis was rejected because stronger magnetic fields did not consistently reduce plant growth or germination. These findings indicate that magnetic fields influence plant development in a non-linear manner, with effects dependent on field strength.

Tao Luke, Mills E. Godwin High School

The Effect of Magnetized Water on the Growth of Phaseolus vulgaris

The purpose of the experiment was to determine if increasing the number of cycles, the water was magnetized for would increase its effects on *Phaseolus vulgaris* (common bean). This research is important to the real world due to many areas having poor growing conditions for crops. The results of this experiment can be used to determine whether magnetized water could be utilized to boost crop growth in areas such as these. Water was magnetized for either 1, 2, or 3 cycles and then applied to the plants. The control that was used in the experiment was regular tap water. It was hypothesized that if the number of water magnetization cycles was increased, then the plants would grow taller. The results revealed that all the plants treated with magnetized water grew taller, on average, compared to the control. However, the plants watered with water magnetized for 2 cycles had an average height far greater than the rest. A t-test was done on the data, and it revealed that the data was significant for 2 cycles vs. the control, but not significant for 1 or 3 cycles vs. the control. The results did not support the research hypothesis. It is believed that the results may be due to the fact that water

is diamagnetic, meaning magnetization is temporary and doing it multiple times does not increase its “strength”. This research could lead to further studies that investigate the effects of magnetized water on other plants, and differences between different water magnetization methods.

Bandi Tejashree, Mills E. Godwin High School
The Effect of Homemade Fertilizers on Plant and Leaf Growth

The purpose of this experiment was to determine which homemade fertilizer affects plant growth and leaf development the most. Plants are sources of oxygen and food, which are vital for humans. For plant production to increase, fertilizers are used. However, homemade fertilizers are safer and cheaper compared to store-bought ones. It was hypothesized that if coffee grounds were added to the plant, then the plant would become the tallest and produce the most leaves. The dependent variables were plant growth and leaf development. Spinach plants were treated with coffee grounds, banana peels, eggshells, and no fertilizer as the control. Each fertilizer was applied to 25 plants, totaling 100. The plants were grown under the same conditions, and 0.5 grams of each fertilizer were added. The plant growth and leaf development were measured every 5 days for 20 days. The data was analyzed using a t-test for plant height and a chi-square for number of leaves. Results showed that eggshells produced the tallest plants, with a mean height of 5.4 cm, while coffee grounds produced the shortest at 2.0 cm. The no fertilizer and eggshell groups produced the most leaves (median of 5). Only coffee grounds were significant in the t-test, while all fertilizers were significant in the chi-square test. The hypothesis was not supported by the results. Coffee grounds experienced least growth and produced the fewest leaves. This is because they were placed on top of the soil instead of mixed in, which limited nutrient absorption.

Chemistry A (HS CHM-A)

Rodney C. Berry Chemistry Award
First Place
Saravanan Barathi, Mills E. Godwin High School
Development of Anthocyanin-Based Colorimetric pH Sensor Films for Intelligent Monitoring of Shrimp Spoilage

Shrimp spoilage occurs rapidly due to microbial protein degradation, which produces basic compounds such as ammonia and trimethylamine and causes an increase in pH. Because these chemical changes precede visible decay, a pH-responsive indicator film may allow earlier detection. Anthocyanins are natural pigments that undergo reversible structural transformations depending on hydrogen ion concentration, resulting in visible color changes across different pH levels (Khoo et al, 2017). This study investigated whether anthocyanin based biodegradable films could function as intelligent pH indicators for shrimp spoilage and provide a low-cost, sustainable alternative to synthetic sensors. Anthocyanins were extracted from red cabbage (Brassica oleracea), blackberry (*Rubus fruticosus*), purple yam (*Dioscorea alata*), and black rice (*Oryza sativa*) using aqueous methods. Extracts were incorporated into gelatinized starch films plasticized with glycerin. To fabricate the films,

6 grams of cornstarch was heated with distilled water to induce gelatinization, 2.5 mL glycerin was added as a plasticizer to improve flexibility, 20 mL anthocyanin extract was mixed into the solution, and the mixture was cast into molds and air-dried to form thin biodegradable sheets. Spectrophotometric calibration was conducted across pH 2–10, and 25 trials were performed per pH level. One-way ANOVA was used to determine statistical significance in absorbance differences. Blackberry extract demonstrated statistically significant absorbance variation across pH levels ($F(4,120) = 13.223$, $p < 0.001$), while red cabbage extract did not show significant variation ($p = 0.208$). Purple yam extract was unsuitable for spectrophotometric analysis due to opacity, and black rice extract showed minimal spectral differentiation.

During nine hours of shrimp putrefaction, blackberry films exhibited the most distinct and stable color transition, while frozen controls showed no change. These results indicate that anthocyanin source significantly influences pH responsiveness and functional film performance. Blackberry-based films demonstrated superior statistical differentiation, visual detectability, and mechanical stability. Although extraction variability and approximate pH measurement methods have limited precision, the findings support the feasibility of anthocyanin-based biodegradable films for intelligent food spoilage monitoring. Further optimization of extraction purity and film uniformity may enhance sensitivity and improve real-world applicability.

Dr. and Mrs. Preston H. Leake Award in Applied Chemistry
Second Place

Saperstein Margaret, Washington-Liberty High School

The Effect of Different Rapidly Composed, Biodegradable Hydrogel Formulations on Adhesion, Fire Retardation, and Viscosity

Today, wildfires are increasing in prevalence and size. Biodegradable fire retardants are the solution to protect human property facing wildfire, because they eliminate environmental threats from fluorinated “forever” chemicals in traditional foams. Demonstrations last year showed that particle-polymer hydrogels are a promising biodegradable retardant solution. After water evaporation, they form aerogels to extend fire protection duration to >10x water alone. The principal drawback of these gels is the multi-hour formulation time that prevents creation with local water supply at the point of immediate need. This science fair project evaluates hydrogels after a single minute of curing, marking a 100x decrease over other hydrogel formulations. This speed ensures fabrication is consistent with using fire hydrants or natural water supplies close to the fire’s edge. The aim of this paper is to identify the most functional, rapid, biodegradable hydrogel formulation in terms of adhesion, viscosity, and fire retardation. To test adhesion, a vertical lift test is used. Viscosity is tested with a dip-type viscosity cup. Fire retardation is tested using a butane torch and popsicle sticks as fuel. Hydrogel formulations include polymer at 1% to 3% by weight, colloidal silica particles (CSP) at 5% by weight, and water. Biodegradable polymers under test include: Methyl 2-hydroxyethyl cellulose (MHEC), chitosan, kappa-carrageenan, and konjac glucomannan. Water alone serves as control. A formulation of 0.75% kappa-carrageenan, 0.25% konjac glucomannan, and 1% MHEC with 5% CSP demonstrates the most compelling balance of performance attributes with a flame retardation of 20x water alone.

Third Place

Mamidala Aditya, Mills H. Godwin High School

The Effect of Glycerol Concentration on the Dissolution Time of Gelatin Sheets in Simulated Gastric Fluid.

The purpose of this experiment was to determine whether glycerol concentration by gelatin mass affects the dissolution time of gelatin sheets in simulated gastric fluid. Gelatin-based films are utilized and studied for controlled drug delivery, and glycerol is commonly used as a plasticizer to modify polymer properties. This makes it essential to test dissolution times, as controlled drug delivery using gelatin thin films significantly relies on precise delivery times to maintain efficacy. Gelatin sheets were prepared with four glycerol concentrations based on gelatin mass: 0% (control), 10%, 20%, and 30%. Each sheet was submerged in simulated gastric fluid containing hydrochloric acid and pepsin, and the time required for complete dissolution was recorded in seconds. It was hypothesized that a 30% glycerol concentration would result in the least dissolution time. The results showed that a 30% concentration of glycerol resulted in the greatest dissolution time, with a mean of 479 seconds longer than 20%, 1,432 seconds longer than 10%, and lastly 2,505 seconds longer than the control. Independent t-tests indicated that all comparisons between glycerol concentrations were statistically significant. The results did not support the research hypothesis but implied a positive relationship between glycerol concentration by mass and increased gelatin sheet dissolution time. The results are likely due to increased hydrogen bonding, increased moisture retention, and the non-disruptive plasticization range of glycerol concentrations used, which strengthened the polymer network. This research supports further studies evaluating the effectiveness of incorporating medication into gelatin sheet compositions.

Honorable Mention

Prabhanand Lalantika, Mills H. Godwin High School

The Effect of Different UV Exposed Bioplastics on Water Absorption

The purpose of study for this experiment was to determine The Effect of Different UV Exposed Bioplastics on Water Absorption. Bioplastics have been a type of plastic that has been used for agricultural, manufacturing, and packaging purposes. When the bioplastics were exposed to UV light their composition starts to deteriorate which affected the durability of the plastic. To determine which plastic was the most durable, the UV exposed plastics were exposed to water, and the mass was recorded before and after the samples were exposed to water for 24 hours. The water absorbance percentage was calculated for every plastic. There was no control for this experiment because there was no basis for comparison in regard to the independent variable groups. It was hypothesized that if cornstarch-based bioplastics were exposed to UV light then it would have a high-water absorption percentage. The results revealed that on average, orange peels had 92% water absorption, Agar had 28%, Cornstarch had 54%, and Potato starch had 194%. The results did not support the hypothesis. A t-test was performed on the data and showed that cornstarch vs orange peel, cornstarch vs agar, cornstarch vs potato starch, orange peel vs agar, orange peel vs potato starch, and potato starch vs agar were all significant. The results were due to the independent

variable. This experiment would help experts understand which UV exposed bioplastic would be the most resistant when exposed to large amounts of water and could lead to further studies about bioplastics.

Honorable Mention
Kannan Sahana
Effect of Temperature on Duration of Glow from Luminol

The purpose of this experiment was to find the effect of various temperatures on the duration of glow from luminol. Luminol is very efficient in crime scenes, used mainly for the detection of blood. However, temperature could affect how long the glow of luminol is present, which might interfere with the documentation of the evidence. Solutions containing 0℃, 10℃, 20℃ and 30℃ and a luminol mixture were absorbed in a dark room. The timer was started immediately after mixing the solution and stopped after the glow had stopped. There was no control for this experiment. It was hypothesized that if the temperature was colder, the glow of luminol will last longer. The results revealed that colder temperatures increased the duration of time the glow of luminol was present. A t-test was done on the data, and it revealed that the data was significant for all levels of the independent variable. The results support the research hypothesis. It is believed that the results are due to the fact that percarbonate decomposes quicker in warmer water. This research could lead to further studies which investigate the intensity of glow from luminol after bleaching the surface.

Honorable Mention
Khandelwal Vihaan, Mills E. Godwin High School
The Effect of Different Rust-Inhibiting Coatings on Iron Oxidation

The purpose of this study was to determine the most effective rust-inhibiting coating for preventing iron oxidation by comparing oil, paint, and powder coating to an uncoated control. Iron corrosion poses significant challenges to infrastructure durability due to its vulnerability to oxidation caused by the atmosphere. It was hypothesized that powder coating would minimize mass change by providing a more uniform, durable barrier. Twenty-five identical iron nails were assigned to each of four groups (n=100 total). The control group remained uncoated, while experimental groups received oil, paint, or powder coating. All nails were exposed to natural outdoor conditions for 14 days. Mass change, indicating oxidation, was calculated from measurements before and after exposure by using a digital scale accurate to 0.001 g. Powder coating exhibited the lowest mean mass change (0.001 g), followed by oil (0.008 g), paint (0.016 g), and control (0.036 g). Independent two-sample t-tests confirmed all pairwise differences were statistically significant ($p < 0.05$, df=48, t-values > 9.6). These results support the hypothesis that powder coating provides superior protection against iron oxidation due to its low porosity and uniform application.

Stavella Julian, Central Virginia Governor's School for Science and Technology
The Effect Varying Brands of Deionization(DI) Resin have on the Efficiency of Salt Removal Through Filtration.

This study was conducted for the purpose of determining if different brands of deionization resin have a different resulting salt content remaining after filtration.

Three commercially available resin brands (TL Reefs, Awesome Aquatic, and AKM) were chosen and tested to determine if any were better or worse than the rest. Each of the three overall trials consisted of the same deionization system and initial salt content, with the brand of resin being the only change. Data was collected by a salinity sensor, measuring salt present after filtration in a collection of 18 total measurements per resin across each trial of the filtration system. Following collection, the data was analyzed using a one-way ANOVA followed by a post-hoc Tukey test. One of the brands of resin (TL Reefs) showed significance between the rest with a p-value of 0.01 compared to the alpha value used of 0.05. With this significance, it can be concluded that some resin brands may be compositionally better at successful salt filtration than the rest and are more dependable for use commercially and communally all around the world.

Tejal Gogineni, Clover Hill High School

The Effect of Type of Milk (Whole, Coconut, Oat, Soy) on the Amount of Fat Found in Each Type

A high fat content in milk leads to obesity complications in pregnancy for young women. Different types of lactose-free substitutes, such as coconut, oat, and soy milk are replacing whole milk, due to the increase in lactose-intolerant people, but the actual fat content of each milk varies significantly. Whole has significantly much more research on the topic pertaining to its fat content, but plant-based milks, which have been expediently rising, do not have as much information on their fat contents. This experiment was done, in order to determine the true fat content of whole, coconut, soy, and oat milk. The chemical components of this experiment, which are sulfuric acid and amyl alcohol were responsible for conducting the levels of fat in the 4 milks (coconut, whole, soy, and oat milk), through the separation of fat in the milks. The fat content that was retrieved through the separation of fat in the milks was pipetted into Eppendorf tubes (calibrated miniature tubes), in order to see how much fat is in the 10.75 millimeters of milk. The ANOVA test was used, in order to test the differences between the values of fat in each of the different milks. Analytical testing displayed that out of whole, coconut, oat, and soy milk, whole milk had the highest fat level, having a mean of 1.72%, while soy milk, which had the lowest mean value had a mean percentage of 0.172%, emphasizing that whole milk had a significantly higher fat content, compared to the other tested milks. The p-value was zero, ultimately supporting the hypothesis, and ultimately rejecting the null hypothesis, as the p-value was less than alpha (0.05). Whole milk has the highest fat content, making this milk highly inflammatory, and advised not to take for people with skin issues, and pregnant women. Future studies should evaluate the fat content in new, and uprising milk substitutes, such as potato milk.

Stines Shelby, Clover Hill High School

The Effect of Reducing the Amount of Sugar Vs. Reducing the Amount of Fat Vs. Increasing the Amount of Protein in a Chocolate Chip

The purpose of this experiment was to determine the structural effect of altering the amount of sugar, fat, or protein in chocolate chip cookies. Obesity rates continue to rise in the United States, furthering the need for nutritional modifications and a less

sugar-filled diet. Implementing more health-conscious changes to common foods while maintaining a minimal effect on the original form encourages greater reduction of harmful ingredients. The hypothesis was: If sugar or fat is removed, or protein is added to a cookie recipe, the resultant average width and height of the cookies will decrease. The sugar and fat were individually reduced by 50%, and the protein content was increased by 13%. After baking for 12 minutes and cooling for 45 minutes, the diameter and height of each individual cookie was measured and included in the average for the current trial. The measuring consisted of inserting a toothpick into the center of the cookies to mark and then measure height, then measuring the diameter along the bottom of the cookies' surfaces. The results of each trial were the mean of each measurement taken from the batch. The average width and height of the recipe with no modifications was 17mm and 107mm, respectively. The mean width and height for reducing sugar by 50% was 28mm and 82mm. The mean width and height for reducing fat by 50% was 15mm and 116mm. The mean width and height for increasing protein content by 13% was 25mm and 102 mm. The average diameter of chocolate chip cookies decreased as a result of decreasing sugar and increasing protein, thus decreasing fat caused an increase in average diameter. The average height of the cookies decreased when fat was reduced, however the mean height increased when protein was increased and sugar was reduced. While all levels produced changes in height and diameter, reducing sugar by 50% yielded the highest overall effect on the structure (ratio of height to diameter) of chocolate chip cookies.

Close Olivia, Southwest Virginia Governor's School
Assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in Honey Produced in Southwest Virginia Apiaries

Polycyclic aromatic hydrocarbons (PAHs) are pollutants caused by incomplete combustion of organic materials and have caused concern due to their toxicity and carcinogenicity. High industrialization and air pollution are associated with increased exposure to PAHs, and there is evidence in previous studies that shows PAHs can enter into food during processing or exposure. This project aimed to provide information on the effects of local environmental pollution on PAH concentration by comparing PAH concentration in honey from several environments in Southwest Virginia. The honey was evaluated using the QuEChERS (Quick, Easy, Cheap, Effective, Rugged, Safe) extraction method with acetonitrile followed by analysis using gas-chromatography mass-spectrometry (GC-MS). None of the target PAHs were detected in any of the samples, which indicates that PAHs were at too low of a concentration to be detected by GC-MS. Sensitivity could be improved in the future by executing a clean-up step after extraction, using GC-MS/MS, using a standard to validate the method, and conducting multiple trials.

Bodduna Yashwanth, Mills E. Godwin High School
The Effect of Amperage on Corrosion Resistance of Copper Electroplated onto Steel

The purpose of this experiment is to find out what amperage density would provide the best electroplating coating against corrosion. Corrosion replacement is one of the most expensive costs of infrastructure and can also pollute water with antibiotic-resistant bacteria. It was hypothesized that 0.05 amps/cm^2 would provide the best

resistance to corrosion. Nails were cleaned with dish soap, water, and steel wool. 75 nails were then flash-electroplated with a nickel electrolyte solution and then they were electroplated with 0.02, 0.05, or 0.08 amps/cm². These nails were then put under a corrosion procedure which consisted of air-drying nails that were sprayed and dipped with vinegar, 12% Hydrogen Peroxide, salt, and lemon juice. The control was 25 nails that were neither flash-plated nor electroplated. The results showed that 0.05 amps/cm² provided better corrosion resistance against corrosive chemicals like vinegar compared to the other independent variables. A t-test was done on the data, and it was supported that the results for 0.05 amps/cm² vs the control and 0.08 amps/cm² vs the control were significant, but 0.02 amps/cm² vs the control was not significant. The results for 0.08 amps/cm² are believed to be due to pitting corrosion, and that the results for 0.05 amps/cm² are because of even plating. The 0.02 amps/cm² had no effect on the corrosion as the plating layer was believed to be thinner, causing an easily permeable layer.

Chemistry B (HS CHM-B)

First Place

Okojie Paul, Central Virginia Governor's School for Science and Technology

The Effect of Ultrasonic Frequency on Dye Degradation

This research aimed to investigate the influence of ultrasonic frequency on dye degradation in solution and on the effectiveness of dyes on cotton fabrics, such as wash-resistance. A dye solution was prepared and subjected to different ultrasonic frequencies for a specified duration, compared to a control group with no ultrasonic treatment. The behavior of dye in solution was assessed by measuring changes in absorbance using a spectrophotometer, comparing the initial and final values of exposure. To evaluate color retention, a sample of the dyed fabric was washed for 60 minutes after ultrasonic treatment, and an image was analyzed with Adobe Photoshop to measure grayscale intensity as an indicator of color change. Slight variations in absorbance and grayscale intensity were observed in the control group, while samples treated with ultrasound showed greater reductions in absorbance, with the highest ultrasonic frequency producing the most decrease. The greatest median decrease in absorbance was .42, and the highest grayscale measurement corresponded to the highest ultrasonic frequency tested. A one-way ANOVA with an alpha level of .05 was used to analyze differences among treatment groups, resulting in a p-value of .002, indicating significant differences. These findings support the hypothesis that increasing ultrasonic frequency enhances dye-fiber interactions by promoting dye degradation in solution, leading to increased dye uptake and retention in fabric. Overall, ultrasonic frequency significantly influences dye behavior and color performance in fabrics, suggesting that ultrasonic pretreatment could be used to improve dyeing processes and has valuable applications in textile processing.

Second Place

Sagar Rohan, Mathematics and Science Academy at Ocean Lakes High School

Evaluating Biofuels and their Components through Energy Output and Carbon Dioxide Emissions

Biofuels have emerged as a promising alternative to fossil fuels because they also release energy when combusted which may be captured for use by humans. Unlike fossil fuels, biofuels originate from renewable biological sources, allowing them to serve as a long-term method of generating power. However, identifying a biofuel that is both clean and energy-dense remains a key challenge to most effectively utilize biofuels for energy. In the experiment, different biofuels were tested by combustion in order to determine their energy release, in the form of temperature change, per amount of carbon dioxide emitted. A similar analysis was also done on the components of the biofuels in order to estimate which structures contributed the highest energy per amount of carbon dioxide released. It was determined that capric, caprylic, and lauric acids were the most effective biofuel components out of those studied. Among the acids present in four or more biofuels, lauric, oleic, and myristic acids performed the highest. Out of the biofuels tested, that made from coconut oil had the highest change in temperature per ppm carbon dioxide released. These results suggest that biofuels rich in capric, caprylic, lauric, oleic, and/or myristic acids may offer a superior energy output to carbon emission ratio compared to others tested within this study, supporting their potential as cleaner alternatives to conventional fossil fuels.

Third Place

Wiegard Brynne, Roanoke Valley Governor's School

Nanoparticles as a Technique for the Removal of Estradiol from Water

The intake of excess estrogen can cause serious damage to an organism, like promoting cancer development (Clevland, 2013). Estrogen transfers into water systems easily, which concerns the public (da Silva, 2025). Although estrogen resists typical water treatment processes, nanoparticles (NPS) can be used to remove it effectively from water, with their adsorption qualities and high surface area (Yang, 2022). The goal of this experiment was to test and compare the estrogen removal effects of metal NPs (silver and iron oxide). Prior research suggested that iron oxide and silver NPs showed promise in estrogen removal and had similar properties, but different methods for removal, leading to the hypothesis that if compared, iron oxide would remove the estrogen most completely. Based on previous experimentation, water solutions with an estrogen concentration of 1000 pg/ mL were prepared. For treatment, 100 mg of each NP type were added to 8 samples of the solution, agitated, allowed 30 minutes of contact time, and removed. An ELISA test was used to determine the absorbance of standards concentrations, and a standard curve was used to find concentrations of the treated samples. After and ANOVA test was performed it was determined that silver removed the most estrogen, reducing the concentration to 14.72 pg/ mL, significantly more than the iron oxide (ANOVA p-value < 0.05). The results showed that silver NPs had a more consistent and effective estrogen removal. Future research should compare different metal NPs, test in natural environments, or include modifications on the nanoscale.

Honorable Mention

Charboneau Henri, Clover Hill High School

The Effects of Fresh vs Frozen Blueberries on the Change in Height, the Density, and the Color of a Blueberry-Lemon Cake

With the importance that baking has on the world today, it is surprising how little science is known about the effects of different conditions of ingredients on the baking process and final result. There is almost no previous research on the results of using fresh or frozen ingredients on baked goods, however, data by T N Kirtaeva and A S Martynova demonstrates that the weight of baked goods increases with the addition of fruits, but that various types of fruits can greatly variate water loss, and therefore density. This experiment utilized various metric measurement tools, along with an RGB app to analyze color of final products. Overall, no significant changes were observed, and the null hypothesis was not rejected in the change in height, with a p value of 0.22 and an average change of height bu 2.18cm for fresh blueberries and 2.22cm for frozen blueberries. The change in density also had an insignificant result and the null hypothesis was rejected as it displayed a p-value of 0.07. Average density of fresh Blueberry-Lemon cakes was measured at 1.90g/2cm^3, while frozen Blueberry-Lemon cakes averaged at 2.02g/2cm^3. Lastly, the null hypothesis was rejected for the theory of color, and original hypothesis was not supported by the data, appearing that fresh blueberries produced a lighter shade of cake than those of frozen blueberries. Fresh blueberries were observed to have created a cake with and average color of 197, 135, 55, whereas frozen blueberries created an average of 203, 142, 55. Overall, there is no correlation between using fresh blueberries or frozen blueberries on the change of height or the final density, however there is a correlation that on average, that fresh blueberries make lighter shaded cakes and frozen blueberries.

Honorable Mention

Davenport Allison, Polineni Anika, Organ Audrey, Governor's School @ Innovation Park

Cyclic Tensile Testing on Self-Healing Hydrogels for Biomedical Applications

This report outlines the experimental design, methodology, and analytical framework developed to evaluate cyclic tensile fatigue in self-healing hydrogels. Hydrogels were synthesized using a two-solution system: Solution A, consisting of a natural polymer combined with deionized water and chitosan, and Solution B, consisting of oxidized dextran dissolved in phosphate-buffered saline. These solutions were combined to form dynamically crosslinked hydrogels, cured in petri dishes, and prepared for mechanical testing. Preliminary results utilized chemical analysis of each hydrogel material and FEA analysis of crack growth using stress and strain mechanics on an online replication. Across all descriptors, the molecules demonstrate a clear gradient of polarity and hydrogen bonding potential, and all materials experienced similar peak Von Mises stress due to equivalent applied forces; however, their strain responses and deformation patterns differed substantially. PVA exhibited the most favorable mechanical behavior, characterized by moderate strain magnitudes and a broad, evenly distributed stress field across the gauge region. Mechanical characterization focused on ultimate tensile strength, healing efficiency, cycles to failure, and crack growth behavior in notched samples. Based on these trends, polyvinyl

alcohol (PVA) hydrogels exhibit superior mechanical performance due to their high effective crosslink density and enhanced energy dissipation mechanisms.

Honorable Mention

Addison Vest, Southwest Virginia Governor's School

The Effect of Color on the Bleed-Through Rate of Highlighters

Highlighter bleed-through is a common problem people face every day, so there is a need to find the best way to minimize the bleed-through rate of highlighters. This project's goal was to find out if the specific color of a highlighter affects the bleed-through rate. The general consensus is that the lighter the color, the lower the bleed-through rate. However, there is a need to research the effects of the specific color. The project's hypothesis was that the specific colors would affect the bleed-through rate of highlighters. This project focused specifically on pastel highlighters with the same general brightness. The highlighters used in this experiment were the pastel highlighters from the brand Artist's Loft. The colors were pink, orange, yellow, green, blue, and purple. During the project, the highlighters were clamped onto a ring stand and lowered onto a blank white piece of Multipurpose Office Paper from the brand Marquee with a paper weight of 75 gsm. The paper was pulled in a straight line and immediately measured using an RGB (red, green, blue) sensor that was composed of three distinct red, green, and blue sensors. The light sensor illuminated the sample with a white light LED (light-emitting diode). The respective RGB reflected light was recorded by the respective sensors. To get a measure of the bleed-through, the difference in reflected light due to the presence of marker as compared to the reflected light to blank paper was looked at. A comparison was done where the reflected light from the bleed-through to blank ratio was compared to the reflected light from the front side relative to the blank. The amount of reflected light relative to the front of the paper ranged from 95% to 111%. The results proved the hypothesis to be false, as the p-value (0.3039) found when comparing the average proportional bleed-through, using an ANOVA test, was not statistically significant.

Sutten William, St. Christophers' School

Pollution driven oxygen depletion in the Chesapeake Bay

Background: The Chesapeake Bay is a place of economic and ecological importance and is the largest estuary in the United States. In order for the bay to stay healthy and biodiverse, the ecosystem must have a certain amount of oxygen dissolved in the water. Because an ecosystem needs oxygen, measuring the level of dissolved oxygen can be used to determine ecosystem health. The dissolved oxygen level can be affected by many variables, such as nutrient pollution like nitrogen and phosphorus, which contribute to eutrophication and oxygen depletion. **Methods:** This study investigated dissolved oxygen (DO) and biological oxygen demand in the winter months along the Rappahannock River tributary of the Chesapeake Bay, following the longitudinal study by the Chesapeake Bay Program. DO was measured initially and after sitting for 5 days at a constant 20 degrees Celsius without exposure to sunlight to determine the Biological Oxygen Demand (BOD). The temperature of the water was also tested for the initial dissolved oxygen reading. **Results:** The dissolved oxygen readings were compared to the Chesapeake Bay Program's Longitudinal Study, the NOAA dissolved

oxygen standards, and peer-reviewed estuary hypoxia studies. The findings indicate that increased nutrient loads from pollutant input likely contribute to measurable oxygen depletion. Also, Winter sampling shows higher dissolved oxygen readings as the water is able to store more oxygen than in the summer. The dissolved oxygen readings correlate with the positioning of the testing sites with regard to water flow and stratification. **Conclusion:** While the tested DO and BOD levels fall within accepted values for each location, continued monitoring of dissolved oxygen over different seasons, potentially introducing stratification of BOD at Sample sites, and comparing with nitrogen and phosphorus levels would be essential to detect long-term trends.

Collier Lorelei, Southwest Virginia Governor's School
Comparing Protein Content in Gluten-Free Flours

The research conducted looked at the difference in protein contents in different gluten free flours: soy flour, almond flour, and oat flour. The point of looking at protein concentrations was to see if a difference in protein content in flour will affect bread, in terms of texture, baking time, and overall characteristics. Currently, protein content in foods are looked at by what protein-rich source people can add to enrich their diets. However, this research is looking at the flour specifically. In order to find the protein content, a hot plate digestion was first completed, followed by a total nitrogen analysis via persulfate oxidation. Then, each flour was used to make bread; while making the bread and when it was completed, characteristics of each loaf were looked at. The soy bread showed signs of high protein content since it had a lot of air bubbles and was elastic. The null hypothesis states that all of the flours will have the same protein content. The alternate hypothesis states that all of the flours will have different protein contents. The results from the bread making showed that the soy flour had the most protein, which did not align with the results from the experiment. The results were analyzed using an ANOVA test, it showed that the oat flour had the most nitrogen per gram of flour. Due to nitrogen being approximate to protein, the findings suggest that oat flour has a greater protein content than soy or almond.

Swain Sanjeevan, Mills E. Godwin High School
The Effect of UV-C Light on The Degradation of Vitamin C in Orange Juice

The purpose of this experiment was to find out if UV-C light had any significant effect on the amount of vitamin C in orange juice. Orange juice samples were introduced to UV-C light for the spans of 3 hours, 6 hours, and 9 hours. The control for this experiment was orange juice with no time in UV-C. It was hypothesized that if vitamin C from Orange Juice is introduced to UV-C light for 9 hours, then the vitamin C content will decrease significantly. After the end of the experiment, the 9-hour UV-C group required an average of 5.0 iodine drops until the vitamin C content was decreased. This amount is seven drops less than the 12.0 iodine drops needed for the control group, showing a noticeable change in vitamin C. A total of six t-tests were performed. Control vs. all 3, 6, and 9 hours were all significant due to the independent variable, and so were 3 vs. 6 or 9 hours and 6 vs. 3 or 9 hours. The results indicate that the data from this experiment was a result of the independent variable and does support the research hypothesis. The research conducted can lead to further studies with other fruits and vegetables to refrain from the loss of vitamins other than vitamin C.

Wilson Alex, Yorktown High School

The Effect of the pH of Daniell Cell's Solution on Its Voltage Production

The purpose of this project was to refine accessible and eco-friendly energy sources. This is important because the recent global energy crisis has caused worldwide price increases of energy sources such as gas and oil, so new affordable energy sources are more important than ever. These expensive traditional energy sources are also harming the environment by producing greenhouse gases that contribute to climate change. This experiment explored Daniell cells, as their components of copper and zinc are affordable and recyclable. The pH of a Daniell cell's solution was altered in an attempt to increase its voltage output. The Daniell cell was built using zinc and copper strips connected by a salt bridge in solutions of $ZnSO_4$ and $CuSO_4$, and a multimeter was used to measure the DC voltage produced. An RO water-citric acid mix with pHs of 1, 2, 3, 5, and 6.5 were added separately to the Daniell cell's solution. The hypothesis stated that its voltage would increase as the pH decreased, as solutions with a lower pH have more H+ ions that bond with electrons and speed up their electric current. The collected data had a p-value of <0.01, therefore, it showed a noticeable difference in the mean voltage of the IV levels. The difference in ranges was also quite high. However, corrosion of the zinc strip affected voltage outputs and made some data unreliable. Despite this, the hypothesis was mostly supported due to the pH 1 battery producing the highest voltage.

Manoj Navin, Mills E. Godwin High School

The Impact of Chemical Cleaners on Stain Removal Efficiency

The purpose of this study is to compare the effectiveness of different cleaners–protease enzyme-based, traditional detergent, vinegar, and water–at removing protein stains from cotton fabric. Water is used as a control because it lacks active cleaning agents, allowing other cleaners' effects to be measured against a baseline. The homemade protease cleaner is prepared through fermentation of citrus peels, sugar, and water, producing natural enzymes that target protein stains. All cleaners are tested on the same fabric size, stain amount, and washing time to ensure fair comparison, and stain removal is rated by stickiness and smell using a 1–5 scale. Chi-square tests determine whether differences are statistically significant. For stickiness, Tide, vinegar, and the protease cleaner each have $\chi^2 = 56.250$, df = 3, exceeding the critical value of 7.815 at $\alpha = 0.05$, showing significant results, while water has $\chi^2 = 3.610$, which is not significant. For smell, Tide, vinegar, and water have $\chi^2 = 12.500$, df = 1, above the critical value of 3.841, indicating significant odor reduction, whereas the protease cleaner has $\chi^2 = 0.360$, which is not significant. These results show that cleaner type affects stain removal, but the effect depends on the property measured. The hypothesis is partially supported as the protease cleaner significantly reduces stickiness but not odor. This aligns with prior research showing proteases effectively break down protein stains. However, enzyme cleaners may require additional components to fully address odor, highlighting areas for improvement and future research.

Anand Balaji Amogha, Mills E. Godwin High School
The Effect of Natural Oils on UV Protection Efficiency

The purpose of this experiment was to find the effects of different natural oils on ultraviolet protection efficiency. Recently, sunscreens have been a consumer need in the cosmetic field, although some contain several chemical ingredients harmful to the skin. In this experiment, natural oils replaced the chemical compounds in sunscreens, which may have different effects on UV light. Ultraviolet Beads were treated with sunscreen mixed with either 2 mL of Raspberry Seed Oil, 2 mL of Carrot Seed Oil, or 2 mL of Coconut Seed Oil. The control that was used in the experiment was no oil. It was hypothesized that UV beads treated with Carrot Seed Oil would be an efficient protectant to UV light than Raspberry Seed Oil, Coconut Seed Oil, and the Control. The results revealed that UV beads treated with the mixed substance of sunscreen and Carrot Seed Oil was a better UV protectant than the other IV levels using the mode. A chi-square test was done on the data, and it revealed that the data was significant for the Expected vs. Carrot Seed Oil, Expected vs. Coconut Oil, and the Expected vs. Control but not significant for the Expected vs. Raspberry Seed Oil. The results did support the research hypothesis. It was believed that the results were due to Raspberry Seed Oil and Coconut Oil having a lower SPF than Carrot Seed Oil. This research could lead to further studies that investigate other types of natural oils on UV light.

Alapilla Deepika, Mills E. Godwin High School
Comparative Impact of Natural and Synthetic Developers on Dermatoglyphic Count

The purpose of this examination involves unearthing the effects of divergent (natural and synthetic) fingerprint detection methods on ridge clarity. For centuries, fingerprinting chemicals such as charcoal powder, turmeric powder, fluorescent powder, and ninhydrin solution have been utilized in forensic science to detect latent (invisible) fingerprints. These methodologies have been acclimatized to surface texture and color to identify criminals in databases, especially natural ones. It was hypothesized that fluorescent powder detection would produce the greatest numerical count of ridges. A control was not implemented due to the superfluous purpose of a standard of comparison with the varying methods. The prints were dusted with charcoal, turmeric, and fluorescent powders in grams with fiberglass brushes and sprayed with ninhydrin solution in milliliters with a spray bottle. The ridges were counted after each method adhered to the sweat and oils produced. The results revealed charcoal powder had a higher mean ridge count than turmeric powder, fluorescent powder, and ninhydrin solution, the results not supporting the research hypothesis. However, a low standard deviation and no outliers implied tight and precise data sets. An t-test revealed significance for charcoal vs. turmeric, charcoal vs. fluorescent, charcoal vs. ninhydrin, turmeric vs. fluorescent, and turmeric vs. ninhydrin, but showed insignificance for fluorescent vs. ninhydrin. It was concluded that ultimately charcoal's dark, potent properties adhered to the prints meticulously and provided high contrasts to lighter surfaces. This research could trigger studies that probe more accessible detection for transgressions in developing countries.

Computational Biology A (HS-COM A)

First Place

Behera Krish, Academies of Loudoun

EpiSight: A Graph Convolutional Network for Epileptogenic Zone Localization in Drug-Resistant Epilepsy Using Phase-Amplitude

Epilepsy is a chronic neurological condition that causes recurrent seizures, significantly hurting quality of life. Drug-resistant epilepsy (DRE) affects ~15 million patients globally, with 30% failing to achieve seizure freedom after surgery due to the inaccurate localization of the epileptogenic zone (EZ). This study proposes a novel machine-learning approach to EZ identification using a Graph Convolutional Network (GCN) trained on Phase-Amplitude Coupling (PAC) derived from intracranial EEG (iEEG) recordings. Using an iEEG dataset of 113 patients from Children's Hospital of Michigan, brain regions of interest (ROIs) were modeled as nodes in patient-specific k-nearest-neighbor (kNN) graphs (k=6). Each node was initialized with PAC summary statistics describing local neural wave coupling, and Convolution layers were used to update ROI features based on neighboring region brain activity. The model was trained for node-level EZ probability prediction using weighted binary cross-entropy loss to handle class imbalance. On a separate test set at the UCLA Mattel Children's Hospital, the model achieved high performance with a 80.2% accuracy, 88.2% AUROC score, and a Hit@1 rate of 99%, revealing that the top-ranked region identified by the model was epileptogenic in nearly all cases. These results were significantly better than the logistic regression control (AUROC 71%) and prior fMRI-based models (AUROC 73%). This research demonstrates that PAC, as a sole biomarker in a graph network, provides a highly accurate tool for locating the epileptogenic zone, helping guide epileptic surgery for DRE patients around the world.

Second Place

Vishnu Vedha, Jafar Aysha, Rosas Jayson, Osbourn Park High School

The Effect of Targeted Atorvastatin Delivery on the Proliferation of Endometriosis

Endometriosis is a chronic inflammatory disease affecting 5–10% of reproductive-age women and is characterized by ectopic growth of endometrial-like tissue, chronic pain, and infertility. Current treatments are limited to surgery and hormonal therapies, which often cause adverse side effects and have high recurrence rates. Atorvastatin, a non-hormonal drug with anti-angiogenic and anti-proliferative properties, has shown limited clinical efficacy due to poor accumulation at lesion sites. This study evaluates whether targeted delivery of atorvastatin using ATWLPPR peptide–conjugated nanoparticles can enhance its anti-proliferative effects in endometriosis lesions compared to systemic delivery. A three-stage computational approach was employed. Molecular docking using AutoDock Vina assessed binding affinities of the ATWLPPR peptide to the VEGFR-2 protein, which is overexpressed in endometriosis lesions. Compartmental pharmacokinetic modeling in COPASI simulated systemic versus targeted drug transport between blood, peritoneal, and lesion compartments. Finally, a pharmacodynamic model incorporated Ki-67–mediated proliferation to evaluate lesion growth under two local atorvastatin concentrations. Docking results showed significantly stronger binding of ATWLPPR to VEGFR-2 (–7.9 to –7.0 kcal/mol) compared to a peptide control (–5.2 to –4.6 kcal/mol). Transport modeling demonstrated higher and more sustained atorvastatin concentrations within lesions following targeted delivery. Proliferation simulations revealed substantial

suppression of lesion growth at targeted concentrations relative to systemic dosing. Repeated-measures ANOVA confirmed statistically significant differences between the targeted and control groups ($p < 0.0001$). These findings support targeted nanoparticle delivery as a promising non-hormonal approach for enhancing endometriosis treatment and demonstrate the potential of computational modeling to accelerate therapeutic development in understudied diseases.

Third Place

Jora Macrea Ian, Blacksburg High School

The Effects of Electromechanical Uncouplers Blebbistatin and BDM on Cardiomyocyte Conduction Velocity

Sudden Cardiac Death (SCD) and arrhythmia account for roughly 25% of 17 million unexpected cardiac failures worldwide. These malfunctions in the heart are caused by irregularly timed ionic electrical impulses called action potentials. In order to investigate the mechanisms of action potentials, researchers commonly image cardiac tissue treated with electro fluorescent dyes that emit light when action potentials propagate. In order to reduce imaging motion artifacts, chemical agents called electromechanical uncouplers are used to uncouple muscle contraction from electrical activity. However, electromechanical uncouplers were hypothesized to have an indirect effect on the ionic currents of action potentials. In the present study, previous optical mapping data collected by the Virginia Tech Poelzing Laboratory from 89 guinea pig experiments were repurposed for investigating the effects of popular electromechanical uncouplers blebbistatin and BDM on cardiac action potential velocity. The experiments were blocked into four groups: one treated with blebbistatin and 2.5mM calcium solution, one treated with blebbistatin and mannitol, one treated with BDM and 2.5mM calcium solution, and one treated with BDM and mannitol. The 2.5mM calcium experiments were selected because it simulates arrhythmia and the mannitol experiments were selected because mannitol simulates surgical conditions. Two-tailed T-tests revealed that BDM causes significant changes to conduction velocity in mannitol from baseline to intervention measurements and that blebbistatin and BDM resulted in significant differences between transverse conduction velocity measurements in surgical conditions. This study suggests that clinically focused optical mapping experiments may be significantly skewed by electromechanical uncoupler choice.

Honorable Mention

Kalagi Shrihari, Maggie L. Walker Governor's School

Computational Identification of Potential Small-Molecule Ligands Targeting KRAS-G12D

The KRAS mutations are among the most common oncogenic drivers, with the KRAS-G12D variant playing a significant role in the development of pancreatic, colorectal, and lung cancers (Haidar et al., 2023). Although considered historically undruggable, we hypothesize that certain small molecules from the ZINC15 database can exhibit stronger predicted binding affinities and more stable docking poses within the KRAS-G12D switch-II pocket than the reference ligand THZ827. To test this hypothesis, structure-based screening was used to evaluate the predicted binding affinities of over 300 candidate small molecules for KRAS-G12D.

In this study, structure-based screening was used to evaluate the predicted binding affinities of small molecules for KRAS-G12D. The three-dimensional structure was obtained from the Protein Data Bank and properly prepared using AutoDock Tools by removing nonessential residues, adding polar hydrogens, and assigning proper charges (Berman et al., 2000; Morris et al., 2009). A known control ligand, THZ827, was used as a reference to establish a baseline binding affinity, and more than 300 candidate ligands were obtained from the ZINC15 database. These candidate ligands were prepared to be in the PDBQT format. Once all the ligands were collected, they were docked using AutoDock Vina via PyRx with the protein under consistent grid and exhaustiveness parameters.

The docking results were evaluated based on predicted binding affinity values and consistency. The reference ligand, THZ827, exhibited a relatively weak binding affinity of approximately -4.3 kcal/mol, while multiple test ligands showed much stronger scores, with the best, Sorafenib, reaching up to -8.2 kcal/mol. Using PyMOL, visual analysis confirmed that the highest-scoring ligand often had very stable and consistent binding poses within the switch-II pocket of KRAS-G12D across multiple runs (Schrodinger, LLC, 2015).

Although docking scores do not alone confirm biological activity, the findings from this study indicate that multiple screened compounds may prove to be promising candidates for further experimentation (Pagadala et al., 2017). The results of this project highlight how molecular docking can be used as an initial screening step to compare relative binding behavior among candidate ligands for difficult oncogenic targets.

Honorable Mention

Li Jonathan, McLean High School

Early Sepsis Detection with AI Models: Predicting Risk and Guiding Clinical Interventions

Background: Sepsis remains a leading cause of mortality in Intensive Care Units (ICUs) globally, necessitating early and accurate detection. While many machine learning models achieve high performance using “idealized” datasets, they often struggle with “Idealized Bias”, assuming laboratory data is as frequently available as vital signs. Furthermore, low sepsis prevalence in clinical settings often leads to high false-alarm rates. We propose a novel two-stage cascaded model design to bridge the gap between high-frequency surveillance and high-confidence biochemical diagnosis.
Methods: We developed a Two-Stage Cascaded Temporal Fusion Transformer (TFT) using the MIMIC-IV dataset. After rigorous filtering to exclude patients with sepsis on admission, we utilized a cohort with an 8.1% sepsis prevalence. Stage 1 utilizes a TFT-based encoder for continuous surveillance of high-frequency vital signs. Stage 2 is an asynchronous refinement module triggered only upon the arrival of new laboratory results. Through Latent State Transfer, Stage 2 integrates the summarized physiological history from Stage 1 with new biochemical evidence to refine the risk surface. Model interpretability was established using SHAP (SHapley Additive exPlanations) to analyze both global feature importance and local patient trajectories.
Results: The proposed framework demonstrates leading-edge performance across multiple temporal horizons. Stage 1 serves as a robust surveillance engine, achieving

an AUROC of 0.824 and a Sensitivity of 0.931 at a 12-hour lead time. As the prediction horizon closes to 1 hour, performance increases to an AUROC of 0.945 and an AUPRC of 0.717 (representing a 9-fold improvement over the 0.08 random baseline). The integration of Stage 2 provides a significant “precision lift”, raising the 12-hour AUPRC to 0.512. SHAP analysis confirmed that the model effectively prioritizes clinical indicators, aligning AI decision-making with established clinical workflows.

Sutton Wyatt, Central Virginia Governor’s School for Science and Technology
The Impact of Injuries on Premier League Athlete Performance

The purpose of this research is to determine how injuries impact the performances of Premier League athletes. To find the results of this experiment, the average performance of 343 athletes was compared to their match rating before injury and after injury. The statistics in this study found that the average pre-injury match rating was 6.48 compared to the post-injury match rating which was 6.49. These averages were found across 343 different data points. The findings resulted in a paired t-test being run, the test was run with an alpha value of .05, which resulted in a p-value of .76 This p-value (.76) indicates that there is no significant difference between these two groups. The research hypothesis: If an athlete suffers an injury, then his post-injury performances will decline, in relation to his pre-injury performances, which was not supported by the data. These results can be used to show that proper and rigorous recovery by premier league players can allow them to return to their same prior level of play. Overall, this experiment shows that many players are able to return to similar performance levels after injury because they can maintain their pre-injury form due to recovery.

Yu, Angie, BASIS Independent McLean
Integrative Proteome-Wide Association Analysis Reveals Genetic Architecture and Therapeutic Insights Across Dental Traits

Dental diseases are among the most prevalent chronic conditions worldwide, yet the biological mechanisms underlying individual susceptibility remain incompletely understood. Although Genome-Wide Association Studies (GWAS) have identified numerous risk loci, most associated variants reside in non-coding regions, creating a functional gap between genetic variation and disease biology. To address this gap, we performed an integrative Proteome-Wide Association Study (PWAS) combining genetic prediction models for 1,689 plasma proteins with GWAS summary statistics from the GLIDE Consortium and the UK Biobank to evaluate associations between genetically predicted protein abundance and ten dental traits. Using a false discovery rate (FDR) threshold of 0.05 for each trait, we identified 62 significant protein–trait associations, primarily in oral ulcers (38 proteins) and denture use (24 proteins). Protein–protein interaction analysis revealed distinct biological architectures: a coordinated immune signaling network for ulcers, centered on hub proteins such as IL12B and IFNGR1, and more diffuse structural remodeling pathways for denture use involving proteins such as DAG1 and LTBP3. Cross-referencing these findings with the Open Targets Platform demonstrated translational relevance. IL12B, identified in oral ulcers, is targeted by the approved drug ustekinumab for immune-mediated inflammatory diseases such as psoriasis and Crohn’s disease, while proteins such as ITGAL and CD22, associated

with denture use, are under clinical investigation in related immune conditions. Although these therapies are not currently approved for the treatment of dental diseases, their roles in immune and inflammatory regulation suggest potential opportunities for biomarker development and drug repurposing. Together, these findings characterize the genetic and functional architecture of dental traits and provide a foundation for translating genetic discoveries into more targeted, and biologically informed approaches in oral healthcare.

Anteneh Salam, Osbourn Park High School
The Effect of Ancestry on the Accuracy of Polygenic Risk Scores for Type 2 Diabetes

The Polygenic Risk Score (PRS) is a measure of an individual's genetic risk to Type 2 Diabetes (T2D). PRS considers the effect of multiple genetic variants. However, most PRS models were developed in European populations, but their performance in African or Asian populations is uncertain. The research aims to test the performance of the PRS in predicting T2D in European, African, and Asian populations using Odds Ratio (OR) and Area Under the Curve (AUC) methods. The independent variable is population ancestry, and the dependent variable is the predictive performance of the PRS. The PRS models created from European populations are highly accurate for Europeans, are moderately accurate for Asians, and a very low level of accuracy for Africans. The PRS models have a very high predictive accuracy for Europeans, with an AUC ranging from 0.78 to 0.81 and an Odds Ratio ranging from 4.5 to 5 times. For Asians, the PRS models have a moderate level of accuracy, with an AUC of about 0.78 and an Odds Ratio of about 3 times. For Africans, the PRS models have a very low level of accuracy, with an AUC.

Computational Biology B (HS-COM B)

AJAS Alternate
First Place
Sundarrajan Pranav, Mills E. Godwin High School
Combating Alzheimer's Disease via Immunotherapy: In-Silico Design of Novel CAR scFv Proteins for Targeted Inhibition of RAGE-Mediated Microglial Activation

Alzheimer's disease (AD) is the most prevalent neurodegenerative disorder, affecting over 50% of 80+ aged individuals worldwide. RAGE is a pro-inflammatory receptor expressed on microglial cells in the brain. Its interaction with molecules like advanced glycation end products (AGEs) and amyloid-beta plaques trigger pro-inflammatory phenotype acquisition in immune cells called microglia, leading to neural tissue damage/degeneration. CAR Treg cell therapy is an emerging immunotherapy treatment where regulatory immune cells called Treg cells are designed to recognize inflammation-indicative biomarkers (e.g., RAGE) and release anti-inflammatory cytokines to halt pro-inflammatory signaling. This research aimed to design novel RAGE-targeting scFvs, which are portions of CAR proteins that interact with target biomarkers (e.g., RAGE) and induce cytokine release, to implement into CAR design. Nine scFvs (S1-S9) were designed with the DiffAB software, and molecular docking was performed to determine binding strength towards RAGE. A higher binding strength

is optimal, indicating that the scFvs effectively bind to RAGE. Additionally, electrostatic interactions between each scFv and RAGE were analyzed using the PLIP server. The top two best-performing scFvs with the highest binding strength, S3 and S4, were further subjected to (1) molecular dynamics (MD) to determine time-dependent stability and (2) molecular docking with BBB adhesion proteins to determine brain permeability. MD revealed that S3 exhibited significantly lower RMSD and Rg fluctuations than S4, indicating it is more structurally stable over a comprehensive timeframe. Furthermore, S3 demonstrated more optimal binding towards BBB adhesion proteins than S4, indicating it can effectively enter the brain and target microglial cells. Overall, S3 outperformed S4 due to its higher stability when bound to RAGE and increased ability to enter the brain, necessary to then target the resident microglial cells. Nonetheless, limitations like constant temperatures/ion concentrations, which misrepresent true physiological conditions, and potential algorithmic errors necessitate validation using hands-on testing. In conclusion, this study presents S3 as a promising therapeutic for Alzheimer's and potential to succeed in future laboratory and clinical testing.

Second Place

Guganathan Ilakkiya, Mills E. Godwin High School

CAR T-Cell Targeting of Prominin-1 to Inhibit Glioblastoma Multiforme Proliferation

This study was conducted to investigate which nanobody exhibits the strongest binding affinity to the glioblastoma multiforme stem cell marker prominin-1, also known as CD133, with albumin used as a control, to explore new avenues for targeted glioblastoma therapy. The research was motivated by the need for more effective treatments for glioblastoma multiforme, as current options often lack specificity and efficacy. It was hypothesized that nanobody 8rw9 would demonstrate significantly stronger binding energy to prominin-1 than the albumin protein. A comprehensive computational approach was employed: protein sequences were retrieved from UniProt2025, structures were predicted with AlphaFoldv3, and visualizations were created using PROTTERv1.0; potential binding sites were identified using P2Rankv1 and ScanNet2022; protein-protein interactions were modeled with HDOCK2.0; binding affinities were calculated using PRODIGY; non-covalent interactions were analyzed with PLIP; and results were visualized using ChimeraX and websites like Biorender.com, and applications like Google Sheets were used to construct tables and graphs of data. Albumin was chosen as a control due to its abundance and lack of specific interaction with prominin-1. The results were shown to indicate that all nanobodies, particularly 8rw9, had significantly more negative mean binding energies to prominin-1 than albumin. Statistical significance was confirmed by t-tests at $p < 0.001$, and low standard deviations were observed, indicating consistency. These findings support the hypothesis that 8rw9 binds more strongly and specifically to prominin-1, thereby highlighting its therapeutic potential. The laboratory risks are eliminated by the computational nature of the study, but limitations are also introduced, such as the need for experimental validation.

Third Place

Oza Naitik, Oza Nisarg, Freedom High School

A Novel Multi-Conformation Graph-Based AI Model for Accelerated Discovery of Anti-Neuroinflammatory NLRP3 Inhibitors in Parkinson's Disease

Background: Parkinson's disease (PD) affects more than 11 million individuals worldwide, and it has been determined that neuroinflammation is an important factor in PD disease progression, which is primarily regulated by the NLRP3 inflammasome. Particularly, the Walker-B motif of NLRP3 is a potential therapeutic target in the NACHT domain, because it mediates ATP hydrolysis. Moreover, drug discovery in wet lab settings takes decades and exceeds billions of dollars, with high failure rates. Machine learning-based and molecular docking approaches are used for binding affinity prediction and virtual screening, but overlook protein flexibility, which is critical for accurate drug binding. **Methods:** Therefore, we developed ConforMAP, a deep learning model that implements a multi-conformation graph attention network to accurately predict ligand bioactivity and binding probability, facilitating the discovery of small molecule inhibitors targeting the Walker-B motif. Ligands were displayed as three-dimensional atom graphs and Walker-B conformations as residue graphs. Molecular docking provided graphs of protein-ligand interactions and was also utilized as input to the model via a cross-attention mechanism. The overall framework predicted binding affinity, binding probability, and the uncertainty of the model, thus supporting reliable virtual screening. We utilized transfer learning on NLRP3 ligands and generated conformations after pre-training graph-based ligand and pocket encoders using protein pocket, ligand bioactivity, and protein-ligand interaction data. **Results:** The results indicate that ConforMAP outperforms state-of-the-art models in binding affinity regression tasks both in pre-training and fine-tuning stages. Virtual screening identified 10 unique small molecule inhibitors, all with pIC50 values of 10.0 nM and binding probabilities of 98.2% predicted by our model. In addition, all compounds had zero Lipinski violations, suggesting highly potent scaffolds that will be further tested in wet lab settings. **Conclusions:** Overall, ConforMAP combines both protein flexibility and ligand geometry to accelerate drug discovery, assisting clinicians in providing anti-neuroinflammatory drugs to improve PD patient outcomes. This framework may also be generalized to other flexible therapeutic targets, supporting broader applications of flexibility-aware structure-based drug discovery harnessing artificial intelligence.

Dr. Smith Shadomy Infectious Disease Award
Honorable Mention

Hu Brandon, Blacksburg High School

Investigating Meteorological Drivers in Models of Aedes Albopictus Population Dynamics

Aedes albopictus mosquitoes are the primary vector for chikungunya, a virus that caused 18.7 million infections between 2011-2020. The life cycles of these mosquitoes are heavily influenced by temperature and precipitation, but the effects of meteorological phenomena are commonly overlooked as a simplifying assumption in many mathematical models. We developed an ordinary differential equation model that includes temperature-dependent and precipitation-dependent parameters for several mosquito life history traits. We created two models: one solely temperature-dependent and one dependent on both temperature and precipitation, and we compared how well they fit to mosquito ovitrap and climate data collected in Sainte Marie, La Réunion

between 2013-2016. We found that the temperature-only model provided the best fit for the entire three-year data set, although it did not effectively capture the peaks. However, when considering the data in individual years, we found that the temperature and precipitation model provided a better fit than the temperature-only model, particularly for years with high peaks in mosquito populations. We discuss the results in the context of improving mosquito population and chikungunya epidemiological models by incorporating temperature and precipitation into those models.

Honorable Mention

Srivastava Samyak, Roanoke Valley Governor's School

Cross-validated Late Integration of Multi-Omics Convergence: A Stability-Constrained Computational Framework for Decoding

Human immunodeficiency virus infection typically requires a lifelong treatment called antiretroviral therapy (ART) that suppresses viral replication. However, a rare subset of individuals can maintain viral loads below detection limits without treatment; they are elite controllers. Although prior studies identified molecular differences associated with elite controllers, the underlying biological mechanisms remain unknown to their full extent, particularly those across multiple molecular layers due to high-dimensional instability and cohort heterogeneity.

This study implemented a stability-constrained, late-integration multi-omics framework to determine whether transcriptomic, metabolomic, and proteomic datasets converge on shared biological themes associated with HIV elite control. Each modality was modelled independently using elastic-net regularized logistic regression with stratified cross-validation. Feature importance was evaluated within each fold, and only features appearing in at least three out of the five folds were retained to allow for minimal fold-specific artifacts. 18 genes and 20 metabolites were generated from this procedure. These stable feature sets were then subjected to hypergeometric pathway enrichment, with a false discovery rate. This reported 28 genes (from Reactome), 7 proteins (from GO), and 3 metabolites (from KEGG) that had an FDR < 0.05. Enriched pathways were then mapped into predefined biological super-themes, and a convergence score was calculated to quantify cross-modal support without the need for shared samples.

The stability constraint substantially reduced the feature space and helped to prioritize reproducible signals. These were categorized into multiple super-themes to check for support across independent modalities, allowing for a structural synthesis into a mechanistic summary figure. These findings would indicate elite control association with coordinated immune and metabolomic programs rather than isolated molecular changes. This framework provides a reproducible computational strategy for robust cross-modal mechanism identification in heterogeneous multi-omic datasets.

Honorable Mention

Madurantakam Shravan, Maggie L. Walker Governor's School

Evaluating the Interactions of Various Kinase Inhibitors with FMS-like Tyrosine Kinase 3

FMS-like tyrosine kinase 3 (FLT3) is a protein located on the cell membrane of lineage-restricted myeloid and lymphoid progenitor cells that regulates the self-renewal and differentiation of progenitor cells. FLT3 mutations are common in acute myeloid

leukemia (AML) and result in uncontrolled proliferation and survival of leukemic cells. AML patients treated with targeted therapy almost always relapse unless patients receive subsequent hematopoietic cell transplantation and the relapsed leukemia tends to be drug-resistant making it difficult to treat. Therefore, there is a need to explore and identify other potential molecules to improve outcomes in patients diagnosed with AML patients. To address this, we used the DataWarrior software to identify human kinases that were at least 80 percent homologous in their structure to FLT3: Mitogen activate protein kinases (MAPK)/ERK2 and mechanistic Target of Rapamycin (mTOR). Subsequently, known inhibitors of MAPK/ERK2 and mTOR kinase were docked with FLT3 protein, and their free binding energy and interactions were studied using molecular docking *in silico*. We found that the best ligands in each group were sorafenib (FLT3 inhibitor), ravoxertinib (MAPK/ERK2 inhibitor) and AZD8055 (mTOR inhibitor) with binding affinity scores of -8.5, -8.4, and -7.9 respectively. Despite the numerical scores of the experiment supporting the conclusion that sorafenib is the best inhibitor, the robust interactions between the ERK2 and mTOR inhibitors and the FLT3 protein could support the idea that these inhibitors could serve as viable adjuncts or complementary treatments. In addition to inhibiting their respective downstream pathways, they may also inhibit the upstream FLT3 pathway, providing a potential for dual action and higher efficiency. However, more investigation and clinical trials would need to be conducted in this area.

Arun Kumar Soumya Akash, Maggie L. Walker Governor's School
Investigating the Potential: Can Artificial Intelligence Strengthen Cybersecurity Systems Through Enhanced Threat Detection and Predictive Analytics?

Cyber-attacks are at a large global scale affecting the economy, society, organizations and individuals. There exist limited studies of cyber-attacks that show the topology of AI-based analytical solutions for generating wide-range cyber threat intelligence. In the landscape of cybersecurity, AI has taken the activity to a new level through the improvement of threat intelligence and its visualization. The findings of this research are based on the new advancements in the field of artificial intelligence including machine learning and natural language processing to enhance the identification, analysis and prevention of threats in cyberspace. It is possible to analyze large quantities of information immediately, recognize signs that point at potential incursions and estimate dangers before they emerge with the use of AI. The research is indicative of the use of AI technologies as valued defense systems, response time reduction, and protection of vital facilities. The research emphasizes the way innovation breathed into cybersecurity by AI prepares a new epoch of security systems which are unyielding and intelligent.

Sibley Kayla, Yorktown High School
The Effect of Different Computer Algorithms on Performance in the Iterated Prisoner's Dilemma

The Iterated Prisoner's Dilemma is a game theory problem used to study cooperation and strategic decision-making over repeated interactions. Previous research, most notably Axelrod's tournaments, demonstrated that simple cooperative strategies, such as Tit-for-Tat, consistently outperform more aggressive approaches.

This experiment investigated whether supervised machine learning models could learn to outperform existing strategies in the Iterated Prisoner's Dilemma. Three neural network-based strategies were developed and trained using different input information: opponent move history, opponent strategy name, or a combination of both. These neural networks were tested against a set of strategies across multiple iteration lengths. Performance was measured by the total accumulated score. Results showed that neural networks trained on opponent move history consistently performed above the average but did not surpass top-performing cooperative strategies such as Generous Tit-For-Tat or Tit-for-Tat. Neural networks trained only on opponent names produced mixed results, while the neural network trained on both history and name consistently performed the worst, likely due to overfitting. Statistical analysis confirmed significant performance differences between the neural networks. Overall, the findings suggest that while neural networks can learn to mimic the behavior of top-performing strategies and outperform average strategies, supervised learning alone is insufficient to outperform the best cooperative strategies in the Iterated Prisoner's Dilemma.

Manikandan Saranya, Mills E. Godwin High School

Breast Cancer Progression on miRNAFrequency and Dianostic Model Detection

The experiment investigated the effect of breast cancer stage on miR-21 expression and the ability of a machine learning model to classify samples as tumor or healthy. MicroRNA expression data were obtained from the Gene Expression Omnibus (GEO), including twenty-five samples of benign, early stage, late-stage breast cancer, and healthy controls. The data extracted were log2-normalized microarray signal intensities, were organized into tables of miR-21 expression values using code. The healthy samples served as the control group. It was hypothesized that if late-stage breast cancer samples were analyzed, then miR-21 expression would be highest, and the classifier would most accurately identify them as tumors. The results showed that early-stage breast cancer samples had the highest mean miR-21 expression, followed by benign, late stage, and healthy samples, suggesting cancer stage influenced miR-21 expression. A Random Forest binary classifier was trained to distinguish tumors from healthy samples. All benign samples were classified as tumor, while some early and late-stage samples were misclassified. T-tests and chi-square tests were performed at a 0.001 significance level, revealing that several comparisons were not statistically significant. The results did not fully support the research hypothesis, as late-stage samples did not show the highest miR-21 expression or the highest classification accuracy. It is considered that variability in expression data and limited samples may have contributed to error. This research suggests that miR-21 alone may not be a fully reliable biomarker for breast cancer tumor classification but inspires future studies using additional miRNAs or larger datasets.

Shirodkar Vihaan, Maggie L. Walker Governor's School

Using a Machine Learning Model to Examine the Effects of Different Factors on Alzheimer's Disease Diagnosis Accuracy

Every year, Alzheimer's disease takes the lives of almost 120,000 people. The disease affects people's thinking, memory, and behavior, causing them to lose their

ability to do rudimentary tasks. To stop Alzheimer's before it starts to take effect, certain risk factors would have to be used for identification early on. This would best be done using a machine learning algorithm. For this experiment, a machine learning model used values in normalized whole brain value (nWBV), Mini-Mental State Examination (MMSE) scores, and age to predict the risk of Alzheimer's in a patient. The hypothesis for the experiment was if a person has a higher MMSE test score and nWBV but lower age, then the chance of Alzheimer's disease will be lower. Coded using Python, the backend of the algorithm retrieved datasets from the Open Access Series of Imaging Data (OASIS). It implemented a random forest method for best accuracy and a web page through React. After putting the values into the model, the results came back. The experiment data concluded that lower age and higher MMSE scores meant lower Alzheimer's risk. However, nWBV values of 0.65 and 0.85, which were the two ends of the spectrum, had the least risk of Alzheimer's. The highest risk stood in the middle of the spectrum. This meant that the hypothesis was partially supported, but not fully. Many other projects and papers related to this one concluded with the same main idea. The model wouldn't replace the proper diagnosis of Alzheimer's disease, but it would help patients recognize that they are at risk, truly changing the medical field.

Saxena Aarav, Maggie L. Walker Governor's School

Evaluation of Deep-Learning Based Multimodal Analysis of Handwritten Images, Pen-Based Time-Series Signals, and Encoded Metadata

Parkinson's Disease (PD) is a neurodegenerative disease caused by the degeneration of neurons in the brain. In 2021, 11.7 million people were diagnosed with PD, and projections show that PD will affect 25 million people by 2050. PD has a 25% misdiagnosis rate and shares similar symptoms with a wide variety of other neurodegenerative diseases, making current manual diagnostics often inefficient. PD disrupts the basal ganglia, a subsection of the midbrain that controls fine motor tasks. Research has determined that handwriting is controlled by the basal ganglia, and changes in handwriting provide key biomarkers for PD detection. PD can be diagnosed through static (image-based) and dynamic (signal-based) handwriting signals. With advancements in technology, Machine learning (ML) allows for automated and highly accurate classification of PD that humans are generally not capable of. The purpose of this experiment was to design and evaluate a multimodal model that can evaluate static and dynamic features and compare it to models that test on only one. The researcher hypothesizes: "If 3 different models were run to classify Parkinson's Disease, one using a convolutional neural network (CNN) to classify images, one using a long short-term memory (LSTM) to classify time-series signals, and a multimodal fusion using a CNN, LSTM, and multilayer perceptron (MLP) to classify images, time-series signals, and encoded metadata, then the multimodal model would produce the strongest results."

The researcher ran a CNN on images, an LSTM on signals, and a multimodal model with images, signals, and encoded metadata, each with k-fold cross-validation. The researcher evaluated the model's performance through accuracy, precision, recall, and F1-score. Overall, the multimodal performed the strongest, having the highest scores for accuracy: 83%, precision: 85%, and F1-score: 83%. The CNN performed the next best, having the second-highest scores for accuracy, precision, and recall, while having the highest for recall: 87%. The LSTM performed the worst, having the lowest

score on every metric. The researcher's hypothesis was supported as the multimodal had the highest accuracy, precision, and F1-score.

Karim Ryan, Deep Run High School

Comparative Generalizability of Pre-trained Automated Prostate MRI Sementation Models

Background:

Magnetic Resonance Imaging (MRI) of the prostate gland studies detailed anatomy of the gland and its zones. Planning for prostate cancer treatment involves accurate segmentation and volumetric measurement. Currently radiation oncologists do this, which is time-consuming and subject to inter-reader variability. Deep learning offers a potential to predict tumor and anatomical boundaries thus allowing expansion of access to treatment esp in limited resource settings. Several deep-learning models have been developed, but are limited by poor boundaries, tissue heterogeneity, physiologic variations in gland morphology and the inter-scanner variation in image acquisition parameters. We aim to test the generalizability of the available pre-trained prostate MRI segmentation models.

Methods:

The Prostate MRI Anatomy, Total Segmentator and MedSAM models were analyzed on 39 cases from the PICAI dataset. Inference was run for the above models and segmentation was performed using the T2W images of each case, and results were both visualized and calculated via Dice Coefficient (DC), Sensitivity, Specificity, and Hausdorff Distance (HD). An Analysis of Variance (ANOVA) and pairwise-t-test was conducted to determine if the difference in mean metrics between the models was statistically significant.

Results

Prostate MRI Anatomy had an average DC of 0.780, Sensitivity of 0.915, Specificity of 0.993, and HD of 115.34 mm. Total Segmentator received an average DC of 0.827, Sensitivity of 0.816, Specificity of 0.997, and HD of 9.84 mm. Finally, MedSAM received an average DC of 0.626, Sensitivity of 0.937, Specificity of 0.952, and a HD of 25.006mm. The differences in mean metrics among the three models and in pairwise comparisons between pairs were statistically significant except the sensitivity of MedSAM vs MONAI where the p value was 0.51.

Conclusions:

TotalSegmentator had the most reliable segmentation performance. While MONAI failed at boundary stability, MedSAM had higher false positive rates. At this time these models can generate an initial segmentation draft for clinician review/edits thus improving their efficiency. Future work is needed for further evaluating the accuracy and fine-tuning the models for improving their performance.

Engineering A (HS EGR-A)

First Place
Bakker Thomas, Central Virginia Governor's School for Science anb Technology
The Effect of Varying Natural Rubber Content on the Mechanical Properties of Rubber Blends

The objective of this study was to investigate how varying the natural rubber content of a polymer blend would affect its tensile strength and elasticity. The hypothesis of this study stated that an increase in natural rubber content of a rubber blend would in turn lead to greater tensile strength and elasticity of the material. To test this, five different rubber blends of varying composition were tested including: natural rubber analogue, a fully synthetic rubber control, and three other blends with natural rubber contents ranging low, medium and high. Tensile strength was measured by applying an increasing upwards force on samples until they exceeded their tensile limit and snapped. Elasticity was determined through calculating Young's Modulus using information gathered by recording the deformation of samples before and after an applied force was added. Collected data was put through a one-way ANOVA test, which produced p-values less than .01 for both elastic and tensile strength, which compared to alpha value of .05 showed significance. A Post-Hoc Tukey's test was then used to further examine the data to find the exact points of significance. From this test it was determined that natural rubber had a direct positive effect on elasticity, but no significant effect on tensile strength. These results partially supported the hypothesis. Ultimately, the study provided some significant data regarding natural rubber's effects on the elasticity of polymer materials but did not observe any significant relationship between tensile strength and natural rubber content.

Second Place
Wood Betsy, Central Virginia Governor's School for Science and Technology
The Effects of Polyethylene Terephthalate in Concrete Mixtures

The purpose of this study was to determine how incorporating plastic affects concrete's performance and whether the modified mixture could be used in real-world applications. This study was conducted at a local company, which gave us access to an Instron Loading Compressive and Tensile Testing equipment. Four types of varying plastic (0%, 5%, 7%, and 10%) samples, each with 10 specimens, were tested through the Instron Loading equipment. The equipment collects the maximum force absorption and deformation that occurred to each specimen. As the force absorption decreased, the ductility significantly increased. After, the data was tested using a one-way ANOVA statistical analysis test. The data and analysis produced a p-value of < 0.01. When compared to the alpha value of .05, the data was found to be statistically significant. A post-hoc Tukey's HSD (Honestly Significant Differences) test was run to compare the differences between each group. The data partially supported the research hypothesis, that incorporating PET plastic into concrete would alter compressive strength and ductility but still allow practical application. In summation, the plastic mixtures, despite decreased compressive strength but increased ductility, can be used in modern applications today.

Third Place
Pratt Lydia, Southwest Virginia Governor's School
The Effects of Nickel Content and Quenching Rate on the Mechanical Properties and Microstructure of ASTM A588 Weathering Steel

Weathering steels such as ASTM A588 are widely used in structural applications due to their ability to develop a protective oxide layer that improves atmospheric corrosion resistance while maintaining mechanical strength. The performance of these steels is strongly influenced by alloy composition and thermal processing, particularly nickel content, which affects phase transformations, strength, and toughness. However, the combined effects of nickel content and heat treatment on the mechanical behavior and microstructure of ASTM A588 steel have not been fully quantified. This study investigated the influence of varying nickel content and thermal history on the mechanical properties and microstructure of ASTM A588 Grade A steel as a foundation for understanding long-term corrosion performance. Experimental heats were produced with nickel contents of 0%, 0.35%, 1.4%, and 1.7%, along with a commercially purchased control material. Samples were subjected to annealing, normalizing, water quenching, and water quenching with tempering. Mechanical characterization included Brinell hardness testing and tensile testing, and microstructural analysis was conducted using optical microscopy. Two-way analysis of variance (ANOVA) was used to evaluate the effects of nickel content, heat treatment, and their interaction on hardness and tensile properties. Statistically significant main effects and interaction effects were observed for both hardness and tensile properties (p-value < 0.0001), indicating that the influence of nickel is strongly dependent on heat treatment. Microstructural observations supported these findings through systematic changes in phase distribution. Future research could evaluate corrosion behavior and patina development during long-term atmospheric exposure of these samples as a function of nickel content and heat treatment.

Honorable Mention

Dixon Daniel, Central Virginia Governor's School for Science and Technology

The Effects of Large Nominal Aggregates on the Structural Integrity of Asphalt Pavements

This study evaluated how increasing nominal aggregate size affects the strength and permeability of asphalt mixtures by comparing traditional dense-graded asphalt with permeable asphalt. Forty asphalt samples were prepared using two aggregate compositions, and compressive strength testing and permeability measurements were used to assess performance. Results showed that permeable asphalt exhibited significantly greater permeability than traditional asphalt, while traditional asphalt demonstrated higher compressive strength. A two-way analysis of variance revealed statistically significant main effects of sample type and test type, as well as a significant interaction between these variables at an alpha level of .05 ($p < .01$). A two-sample t-test further confirmed a statistically significant increase in permeability for permeable asphalt ($p < .01$), while additional analysis indicated that water exposure during permeability testing did not significantly affect compressive strength ($p > .05$). These findings partially supported the research hypothesis, as increased aggregate size improved permeability without evidence of strength degradation due to moisture exposure. Overall, the results highlight an important trade-off between permeability and strength that must be considered when designing sustainable pavement systems.

Honorable Mention

Jansen Erin, Patriot High School

Sustainable Leather Alternatives: The Effect of Zinc Oxide and Microcrystalline Cellulose on Mechanical Properties and UV-Blocking of Sodium Alginate and Gelatin-Based Biomaterials

The negative environmental and health-related impacts of real and synthetic leather production have prompted interest in sustainable, bio-based alternatives that maintain functional performance while reducing reliance on hazardous, resource-depleting processing methods. This study investigated whether sodium alginate-based and gelatin-based biomaterials could be engineered to approximate the mechanical properties of leather and its conventional synthetic alternatives through additive reinforcement. This research examined how zinc oxide (ZnO) and microcrystalline cellulose (MCC), incorporated at concentrations of 5%, 7.5%, and 10%, affect tensile strength, wear resistance, flexural rigidity, and ultraviolet light-blocking. Biomaterials were fabricated using sodium alginate or beef gelatin plasticized with glycerin and reinforced with either ZnO or MCC. Material performance was evaluated using tensile, wear, stiffness, and UV light intensity testing and compared to leather, polyurethane leather, and marine-grade vinyl. Unmodified biomaterials exhibited low tensile strength and limited UV blocking, demonstrating the need for reinforcement. ZnO significantly improved tensile strength and produced complete UV blocking in both biomaterials, with optimal performance at intermediate concentration. MCC produced concentration-dependent increases in biomaterial flexural rigidity that exceeded leather, but reduced wear resistance. The results of this study demonstrate that sodium alginate- and gelatin-based biomaterials can be tuned to achieve application-specific mechanical and functional properties through additive selection and concentration control. This research supports the potential of bio-based materials as sustainable alternatives to conventional real and synthetic leather products, mitigating negative environmental impact and health risks.

Benavides Ruiz Daniela, Clover Hill High School

The Effect of the Camber of Drone Propellers on the Maximum Payload Lifted to a Specified Height by the Drone

The purpose of this experiment was to determine the effects of camber percentage of propeller airfoils on the maximum amount of weight lifted by a quadcopter. The airfoils used in this experiment were the National Advisory Committee for Aeronautics (NACA) airfoils from the 4-series family. The NACA 2412, NACA 6412, and the NACA 9412 were used for the different levels of camber; the NACA 0012 airfoil was the control in this experiment. It was hypothesized that the NACA 6412 airfoil would produce the most thrust when applied to the propellers of a quadcopter and therefore allow the quadcopter to carry more weight. The propellers used in the experiment were designed in Fusion360, 3D printed using PLA filament and then attached to a quadcopter. Each set of propellers was tested on the quadcopter using a lever-type thrust stand to measure the produced thrust. The various propeller configurations, however, did not produce the sufficient amount of thrust needed to lift a payload with the quadcopter. Thus, the thrust produced by the drone was the only data collected during the testing of the propellers. A one-way ANOVA test was performed on the collected data to determine if the data was significant. The test yielded an F-Statistic of

62.82 and a P-value equal to 0; therefore, the data provided significant results, and the null hypothesis was rejected. However, the hypothesis for this experiment was not supported as the NACA 9412 produced the highest amount of thrust, averaging at 101.04g of thrust.

Anthony Christopher, Central Virginia Governor's School for Science and Technology
Evaluating Thermochromic Liquid Crystals for Temperature Monitoring: Color Response and Durability Testing

The purpose of this study was to determine the color-changing behavior of thermochromic liquid crystal (TLC) materials and assess their potential use for solar panel temperature sensing. TLCs were exposed to a range of temperatures, and performance was compared before and after a durability treatment. For each data point, an image of the color response was captured, and a hue value was calculated. To analyze the data, linear regression and analysis of covariance (ANCOVA) were used. The effects of temperature, durability condition (pre or post), and their interaction were tested ($\alpha = .05$). Hue increased approximately linearly with temperature within the tested temperature range in both conditions, with strong r-squared values of .983 for pre-durability and .978 for post-durability, and slopes of 16.61 for pre-durability and 16.70 for post-durability. Temperature significantly predicted hue ($p < .01$), and durability condition produced a small but statistically significant shift in hue, with post-durability values slightly lower than pre-durability values ($p < .01$). The temperature-condition interaction did not have a statistically significant effect on hue ($p = .87$), showing that the durability condition did not significantly affect the temperature-hue relationship. Overall, the hypothesis that hue would increase with temperature with stable slope relationships between durability conditions was supported; however, a small shift in hue values occurred after durability exposure. These results show that thermochromic materials can provide temperature indication but may require recalibration after use.

Yu Ian, Blacksburg High School
Performance Analysis of a 5 Bar linkage pentapod for Martian locomotion

The Martian surface, mapped through the Martian Reconnaissance Orbiter's HiRISE camera, contains a combination of subsurface voids, mare pits, and uneven terrain that hold potential as inhabitable locations for future Martian bases or hold water needed for extraterrestrial life. These areas are inaccessible to current rovers and proposed multileg solutions center around hexapods and quadrupeds, yet the pentapod remains underexplored, demonstrating potential to provide the stability of a hexapod with less power and weight while being more resilient than a quadruped through its fifth limb. This study proposes a pentapod with legs arranged at intervals of 72 degrees radially and an original leg design using a combination of a coaxial five-bar linkage and a linear actuator. This architecture is assessed through a combination of physics-based simulation and physical prototype testing on gait stability, workspace dimension, force distribution, terrain interaction, and slope interaction for feasibility. At a single-leg scale, the results reveal a larger prismatic workspace volume and increased XY-plane torque output with low Jacobian condition numbers. On a multi-leg scale, it is able to maintain stable movement through uneven terrain using a 3+2 tripod gait and consistently

achieves continuous forward movement. Across different slopes, it is able to hold a consistent support triangle to maintain a high stability margin. Overall, it demonstrates potential as an alternative to traditionally used robots and motivates future work developing spring-powered linear actuators to take advantage of jumping in the lower Martian gravity through a kangaroo-based gait.

Grove Mateja, Blacksburg High School
Harmonic-Based Estimation of Coil Misalignment in Low-Power Wireless Power Transfer Systems

WPT (wireless power transfer) systems can be optimized using frequency-based dynamic tuning. Effective tuning requires the control system to know the location of the secondary system's induction coil relative to the chargers. Current literature supports the idea that harmonic appearance can be used to roughly estimate induction coil misalignment in high-power systems. Because WPT systems have two common types of misalignments, radial and axial, the research goal was to see if harmonic signatures could be used to determine both types of misalignments in low-power systems. A WPT system model was used in an experiment where harmonic appearance was the dependent variable. The alignment of the two coils in the system was methodically varied, and the resulting harmonic spectrum was sensed using an oscilloscope. FFT(Fast Fourier Transform) was then applied to extract the amplitude of each harmonic. Amplitudes were then examined across alignment variations to identify trends. The analysis revealed a correlation between radial misalignment and the 2nd and 4th harmonic, a relationship between general displacement and the 3rd, and 6th harmonics. These findings suggest that compound coil misalignment produces recognizable harmonic signatures. This forms the basis for harmonic-based sensing in low power systems.

Cohen Gabriel, Yorktown High School
A LiDAR Haptic Interface to Assist with Blind and Low Vision Navigation

This study presents a smartphone application that uses the iPhone's built-in LiDAR sensor to deliver real-time haptic feedback for blind and visually impaired indoor navigation. The app translates depth data into continuous vibrations indicating obstacle proximity as well as transient clicks indicating edges, using the iPhone's Taptic Engine. A five-person usability study with blind and visually impaired participants yielded a mean System Usability Scale score of 84.5, well above the 68-point benchmark for above-average usability. Task-effectiveness ratings averaged 4.0-4.4 out of 5 across all items. Participant feedback drove iterative improvements including an AI-powered scene description feature. No participant wished to replace their white cane, but several indicated the app could serve as a useful supplement. Results suggest that LiDAR-based haptic feedback on a consumer smartphone is a viable, low-cost approach to augmenting existing mobility aids.

Adidam Vaishnavi, Langley High School
Text Based Steganography using Prepositional Encoding with LLMs

Steganography aims to hide information without triggering suspicion. Traditional text-based methods rely on pre-defined cover texts vulnerable to statistical detection.

This research developed a novel system using preposition-based encoding with a commercial off-the-shelf LLM to generate cover text. By leveraging LLM-generated text, the system sought to bypass automated statistical tools and human reviewers. Testing showed that the system maintained a character error rate of less than 5.5% for messages up to 40 characters. An average character error of approximately 7.8% was observed across the full test range (up to 50 characters), with a sharp increase in error past the 45-character mark. This research demonstrated a fundamental trade-off between textual naturalness, message capacity, and transmission accuracy in generative steganography.

Sogutlu Onur, Mills E. Godwin High School
Optimization of 3D-Printed Gear Designs for Durability

Optimization of 3D-Printed Gear Designs for Durability Abstract Additive manufacturing, commonly referred to as 3D printing, allows for rapid and cost-effective production of gears. This makes 3D-printed gears attractive for prototyping. However, 3D-printed gears suffer from poor durability and wear, restricting their use in more demanding applications. This research aims to optimize the quality of 3D-printed gears by studying the effects of different tooth structures and infill patterns on gear durability. Six different gear designs were tested, featuring either filleted or non-filleted roots and various infill geometries (grid, triangle, or gyroid). All gears were made using polylactic acid (PLA) and a 40% infill density. Gear durability was measured using a custom, low-cost testing rig. Each set of gears was run at approximately 6400 rpm until failure. The results demonstrated that gears with filleted roots were able to last for a significantly greater number of cycles when compared to gears with non-filleted roots. This confirmed that filleted roots were able to improve durability by reducing areas of concentrated stress. Additionally, the grid infill pattern displayed superior performance compared to the triangle and gyroid infill patterns, likely due to increased rigidity. These findings show that relatively simple design modifications can substantially improve the durability of 3D-printed gears, ultimately leading to greater applicability

Engineering B (HS EGR-B)

First Place

Jackson Joanna, Southwest Virginia Governor's School
Screwable Modular Components for the Pylon of Pediatric Leg Prosthetics

Children need to have access to affordable, adjustable prosthetics to accommodate their rapid growth. With the use of 3D modeling and printing, an adjustable pylon, which is what connects the foot to the socket, was created. Multiple segments of 60 millimeters and screws were created for ease of adjustability. Clamps were added to secure the outer edges of each segment. The segments were then 3D printed. A series of tests were completed using Fusion360 to determine the structural stability of the pylon. The pylon was tested against different heights of itself. This project focused on structural buckling and static stress tests. Structural buckling and static stress tests were applied at every height of the pylon. Both of these tests suggested the pylon could hold a significant amount of weight, no matter the height. The structural

buckling and static stress tests are key for the pylon to be considered safe to walk on. The results suggest a possibility for the pylon to be considered structurally stable. With this model of an adjustable pylon, children can have convenient, affordable, and adjustable prosthetics. More segments ranging in length can be added to this project for precise adjustments. More testing could be performed on said segments to study structural stability. These findings are significant because they demonstrate a way for children who are amputees to live more comfortable lives.

Second Place

Medavarapu Svaran, Thomas Jefferson High School for Science and Technology

A Spatiotemporal Transformer Architecture for Long-Term Post-Wildfire Vegetation Recovery Forecasting

Wildfires are becoming more frequent and more destructive, and one of the hardest problems that follows in their wake is predicting how vegetation grows back. Recovery is not a clean, linear process. It is shaped by dozens of interacting factors that play out across space and time, sometimes over years.

The tools previously used to study this, from statistical models to convolutional neural networks, perform well at capturing local patterns but struggle to model how distant parts of a landscape influence each other, which limits them to short-term predictions or forces them to flatten complicated dynamics into oversimplified parameters. This paper presents a Spatiotemporal Vision Transformer (SVT) built specifically to address this problem. Using satellite and environmental data from 41 historical wildfires across California, the model takes 12 months of post-fire observations as input and forecasts the next 24 months of vegetation recovery across the entire affected landscape.

It does this through two core components:

a Vision Transformer backbone that captures broad spatial patterns, and a temporal transformer that models how those patterns evolve over time.On a heldout validation se t, the model achieves a Structural Similarity Index (SSIM) of 0.62. Beyond raw predictive accuracy, we demonstrate that by extracting biological growth rates from the model's predictions, the model appears to have internalized real ecological recovery dynamics, achieving a median error of 0.317 on derived growth rate estimates.The result is a tool t hat not only predicts recovery at a broad scale but preserves fine-grained spatial detail in a manner that could meaningfully support land managers in post-fire decision making.

Third Place

Garg Arjun, Thomas Jefferson High School for Science and Technology

StrokeShield: A Noninvasive Thermoelectric Neck Patch for Targeted Carotid Artery Neuroprotection via Hypothermia in Acute Ischemic Stroke

Ischemic stroke can cause irreversible brain damage within minutes due to rapid metabolic failure and excitotoxic injury, yet current hypothermia-based neuroprotection methods are invasive, slow, or impractical in prehospital settings. This project investigated whether a portable, noninvasive thermoelectric neck patch could rapidly and safely induce targeted carotid artery cooling sufficient for neuroprotective hypothermia. A Peltier-based cooling patch was designed, constructed, and then tested on a biomimetic phantom model simulating skin, subcutaneous tissue, muscle tissue,

and a perfused carotid artery at physiological flow with temperature sensors embedded at multiple depths measuring cooling dynamics over time. Patch application reduced arterial temperature to 31.9°C in 15 minutes (cooling rate of 0.334 °C/min), demonstrating superior cooling at clinically relevant depths. Additionally, a biochemical fluorescence stroke-simulation assay using the pH- and temperature-sensitive dye fluorescein validated hypothermia's protective effects: hypothermia at 32°C significantly slowed fluorescence decay compared to 37°C, indicating reduced biochemical degradation under hypothermic conditions. Furthermore, heat transfer modeling, using Pennes' bioheat equation in 3D cylindrical geometry with layered tissue properties and physiological accuracy, mirrored experimental findings; moreover, cerebral metabolic rate modeling of oxygen showed 33.1% metabolic reduction. Collectively, these findings demonstrate the feasibility of rapid, selective carotid cooling and support hypothermia's protective biochemical effects while also highlighting a low-cost, noninvasive approach that achieves faster targeted cooling than existing prehospital technologies, positioning the patch as a promising state-of-the-art device for preventative stroke.

Honorable Mention

Maria Benavides Ruiz, Clover Hill High School

The Effect of Altering the 3D Printed Surface Texture of an Airfoil, Tested in a Subsonic Wind Tunnel, on the Resultant Drag

The purpose of this experiment was to determine the effect of different surface textures on the resultant drag of an airfoil. This experiment studied four different surface textures: smooth, golf ball dimples, bumpy, and riblet texture. The smooth texture was the control. Each texture was applied to the upper surface of a NACA 0015 airfoil. The airfoils were designed in Fusion 360 and 3D-printed using PLA filament. Each airfoil was then prepped for testing in a homemade, subsonic, open-circuit wind tunnel. During preparation, all four airfoils were sanded down to remove layer lines created from printing and then labeled with their respective titles. The airfoils were then individually tested in the wind tunnel, fashioned with a load cell to record the data that each airfoil generated. Each airfoil was placed inside of the wind tunnel and tested in 30 second increments with a two-minute break between each trial. On average, the golf ball dimpled airfoil produced the least amount of drag while the smooth airfoil produced the greatest amount. It was recorded that the golf dimpled airfoil produced 0.24 g of drag force while the smooth airfoil produced 0.32 g of drag. A one-way ANOVA test was conducted on the data, which returned a P-value of 0.00591, rejecting the null hypothesis as it is less than the alpha value of 0.05. It was hypothesized that the golf ball dimples would produce the least amount of drag while the bumpy surface would produce the greatest amount of drag. The hypothesis was partially supported by the data provided by the experiment.

Cailles Jacob, Central Virginia Governor's School for Science and Technology

The Effect of Applied Forces on the Energy Harvested from Piezo-Electric Materials

The purpose of this study was to determine if there was a significant relationship between the force applied to a piezoelectric disk and the voltage output from an energy harvesting module. The research hypothesis for this experiment was that the greater

the force applied to the disk, the greater the voltage output would be. To determine this relationship, a piezoelectric was soldered to an energy-harvesting converter module, and the output voltage was measured using a voltage probe. The disk was mounted on top of a force-sensing plate, and both sensors were connected to a computer to collect data simultaneously to determine their relationship. For a total of 15 trials, force was applied to the disk at a consistent rate for 30 seconds, where samples were collected at a rate of 10 samples per second. From this data, the average voltage and average force were calculated and then graphed to perform a linear regression test to determine their relationship. The linear regression test resulted in significance, with a p-value of <.01 and a slope of .19. This slope indicates that there is a positive correlation between the force applied and voltage output, and the research hypothesis was supported. This positive relationship could be used in further research to examine other applications and limitations of piezoelectric materials.

Lovelace Nolan, Central Virginia Governor's School for Science and Technology
Simulation-Based Evaluation of Powered-Landing Control Strategies Under Wind Disturbances

The purpose of this research was to evaluate whether an adaptive suicide-burn controller improves operational robustness and mission success in powered rocket landings compared to a late-ignition baseline controller under disturbed conditions. A simulation-based testbed was developed to model rocket landings subject to wind disturbances, and 200 paired landing simulation trials were conducted to evaluate controller performance using landing error, trajectory deviation, path deviation, disturbance response time, fuel usage, and mission success rate. Descriptive analysis revealed that the late-ignition baseline controller achieved lower mean landing errors and trajectory deviations, while the adaptive suicide-burn controller achieved higher mission success rates, lower fuel usage, and lower path deviations. Paired t-tests revealed statistically significant differences throughout multiple measures (a= .05, P-value < .05). Two-Way ANOVA was also used to evaluate the effects of controller type and wind severity on select performance variables. The research hypothesis that the adaptive suicide-burn controller will improve operational robustness and increase mission success compared to a late-ignition baseline controller when tested under various disturbance conditions was partially supported. The adaptive controller increased robustness and mission success despite tradeoffs in average performance metrics. These findings suggest that adaptive control strategies may offer improved reliability for autonomous landing systems while operating under strict safety constraints.

Holman Heather, Southwest Virginia Governor's School
Best Solution for the Back Window Against Blinding Headlights

Driving at night presents a unique set of challenges on its own, but with advancements in modern technology, it is downright dangerous. These powerful headlights offer clear benefits when driving alone at night, as they improve a driver's ability to see the road ahead and navigate challenging conditions. However, the increased brightness also presents new challenges, especially in situations where multiple vehicles of different heights share the road. When a larger vehicle is behind a

smaller vehicle the driver can often find themselves temporarily blinded by the intense light of headlights from the taller vehicle behind them. This temporary blindness can create dangerous driving conditions by significantly reducing visibility and reaction time, increasing the risk of accidents, stress, and distracting drivers. In order to reduce the effects of bright headlights 5 tints were tested to see which blocked light the best. The tints tested were; Amber, Pink, 20%, 50%, and Reflect. The null hypothesis states that all of the window tints are the same and none perform better than another. The alternate hypothesis states that some tints perform better. The data was then compared against the other window tints using a two-way ANOVA test with alpha equaling 5%. It was concluded that some of the results were statistically significant while others were too close to be statistically significant. It was shown that Reflect, and 50% performed better than the rest. Yet despite the results of the experiment, it is important to note the legality of using tints on windows. In the state this experiment was done in, some are illegal. Further experiments could build off equations like: Do blue tinted style headlights change the results? Or the experiment could be done on a vehicle so the variable regarding the curve of the rear windshield could be accounted for.

Borum Brendan, Central Virginia Governor's School for Science and Technology
An Investigation of Aerodynamic Performance Across Three Wing Shapes Using CFD Simulation

The purpose of this study was to find which wing shape (trapezoidal, sweptback, delta) is most aerodynamically efficient. This study was conducted at my local high school. I used an HP EliteBook laptop provided by the school. The wings were modeled in AutoCAD and kept in the parameters of 20mx20m. In conjunction with SimScale's Incompressible CFD, with a K-Omega SST turbulence model. The average pressure readings were used in conjunction with the wing parameters to come up with the lift and drag coefficients. I used the coefficients to find the lift and drag generated by each wing. Results showed that there was a significant difference in drag generated by each wing, while there was no significant difference in lift, lift coefficients, or drag coefficients. The drag generated showed a p-value of $<.01$ with an alpha value of .05. This showed that the delta wing generated the least drag and the sweptback wing generated the most. An ANOVA test was used to analyze the results, with a post-hoc Tukey test to determine which groups were significant. These results partially supported the hypothesis that wings with smaller surface area would generate less drag but did not have enough significance to show that wings with larger surface areas would generate more lift. This research can be used to determine what wing shape will be best for specific applications, whether in commercial or private aircraft design.

Moyer Mia, Central Virginia Governor's School for Science and Technology
Does Seaplane Aluminum Withstand Saltwater Corrosion Effectively

The purpose of this project was to determine if different water environments affected the fatigue life of aluminum found in seaplanes. Aluminum samples were split into groups and put in one of five solutions: air, distilled water, distilled water taken out, salt water, and salt water taken out. Once a week, the samples were sanded to factor in oxidation. After four weeks in their prospective solution, the samples were stressed in an Instron machine. Each sample was flexed up and down until it broke. The

maximum push force and pull force was recorded for each sample. An ANOVA test was conducted to compare the push forces and revealed a P-value of .02. Compared to an alpha value of .05, this revealed significance and a post-hoc Tukey test determined differences between samples soaked in distilled water taken in and out and samples soaked in salt water taken in and out, as well as samples soaked in distilled water that stayed in the solution. These results went against the research hypothesis that the aluminum samples taken in and out of salt water will have the highest decrease in strength because the repeated exposure will cause faster corrosion. This shows how different water environments can affect fatigue life of aluminum seaplane hulls.

Lokar Jacob, Central Virginia Governor's School for Science and Technology
The Relationship Between Tread Geometry and Friction in 3D-Printed Thermoplastic Polyurethane (TPU)

The purpose of this study was to expand public knowledge of how tire types affect a vehicle's traction on common terrains. The hypothesis was that, since asymmetric treads are designed for water dispersion and cornering stability, they will exhibit the highest static friction across most terrains. In contrast, bald tires, lacking channels for water or debris, will exhibit the lowest. The testing consisted of five common tire patterns: bald, horizontal, directional, symmetric, and asymmetric. Each tread was pulled with a force, parallel to the terrain sensor, to measure static and kinetic friction along the same trail across five terrain types: ice, dirt, mud, dry asphalt, and wet asphalt. After testing, the data were compiled into a Data Classroom sheet, and a post-hoc Tukey's test was conducted, leading to 625 statistical analyses. The analysis revealed statistically significant differences in the data but only partially supported the research hypothesis, finding that the bald tires performed the worst on average, while symmetric and directional tires performed better than asymmetric tires. In summary, the type of tire used on different terrains affected the vehicle's traction.

Abdel Motaleb Mohamed, Blacksburg High School
How do different mycelium species and substrate formulations influence soil erodibility and strength?

Mycelium is the root-like network of fungi that grows inside substrates such as wood or agricultural waste. Scientists are increasingly studying mycelium because it can form strong materials and can grow using waste products. Research shows mycelium can act as a natural glue that binds soil particles together forming its own kind of soil stability. The growth that we will see in this project will most heavily be impacted by the environment and substrate that the mycelium is grown in. In my research project I created unique samples that differ in the substrate and species of mycelium to understand what mixture has the best results out of 3 common fungal species and 5 common substrates for mycelium. Samples were prepared using mixtures consisting of 25% water, 20% organic food substrate, 15% clay, and 40% Ottawa sand by total mass. Fungal inoculum was added at 0.05% of the food substrate mass. Samples were incubated for seven days at approximately 90°F and 68% relative humidity to promote fungal colonization. Following incubation, samples were soaked in water for 24 hours to simulate high moisture environmental conditions. Material properties were evaluated using EFA, fall cone testing, water content measurement,

pH, and rheology. Results include noticeable differences in strength, water absorption, and mechanical properties between fungal treated samples and the control sample (Soil, Water, and Clay). This research contributes to the development of sustainable, bio-mediated soil stabilization methods and betters our understanding of how soil and fungi interact for engineering purposes.

Foutz Vivian, Western Albemarle High School
Design and Evaluation of a Safety-constrained AI System to Enhance Adolescent Executive Functioning

Adolescents face growing demands to plan, prioritize, initiate tasks, regulate emotions, and manage distractions – skills collectively known as executive functioning. Limited access to individualized support contributes to stress, procrastination, and disorganization. This study introduces Cognify, a domain-specific, safety-constrained conversational AI system designed to enhance executive functioning through structured, text or voice, natural language interaction. Cognify provides task decomposition, prioritization, procrastination mitigation, and accountability check-ins, while enforcing guardrails on tone, content, and response structure to reduce hallucination, drift, and inappropriate outputs. Cognify is developed through a three-stage engineering workflow: custom interface deployment, iterative prompt refinement, and simulation-based testing using the OpenAI Developer Interface and Python API. Two theory-grounded hypotheses and system performance are tested using a 2 × 2 design varying user type and topic type, and along seven outcome metrics. Across 600 sessions, Cognify exhibits greater success with lower-stress users, but displays similar effectiveness across cognitive and emotional executive functioning topics. Machine learning analysis further identifies user satisfaction and engagement as the strongest predictors of success. These findings demonstrate that a safety-constrained, domain-specific AI system can support structured cognitive behavior in adolescents. Cognify reframes prompt engineering as a form of system control, illustrating how human-centered AI can expand access to elevate quintessential life skills.

Engineering C (HS EGR-C)

AJAS Alternate
Virginia Peninsula Engineers Engineering Award
First Place
Nathan Kim, John Randolph Tucker High School
Microstructure-Resolved Design of Porous Dielectric Membranes for Ultrathin Capacitive In-Stent Intracranial Pressure Sensors

Recent advances in non-surgical, in-stent pressure sensors have allowed for minimally invasive, continuous monitoring of intracranial pressure (ICP), overcoming traditional limitations in ICP monitoring. However, the literature on these advancements fails to investigate factors that affect the microstructural mechanics of the dielectric membrane, despite their key influence on the electromechanical performance and mechanical stability. This study addresses these shortcomings through microstructural studies of sacrificial three-dimensional (3D) templates and their resulting

electromechanical performance. Hence, a monodisperse sacrificial template was chosen to systematically examine the correlation between pore-scale architecture—porosity and pore size—and the electromechanical response across physiologically relevant pressure ranges for ICP monitoring. Intermediate porosity and pore-size microstructure in the dielectric layer made with monodispersed particles demonstrated an optimal sensitivity that did not compromise the linearity or mechanical longevity of the capacitive pressure sensor (CPS). When the optimized porous dielectric membrane is under ultrathin dimensions in a non-surgical in-stent intracranial pressure sensor, it accurately detects low-amplitude pressure oscillations within the clinically relevant ICP range without drift. By exhibiting and elucidating the link between pore size/porosity and sensing performance of CPS under ultrathin constraints, this study provides a materials-level foundation for improving the sensitivity and clinical reliability of future pressure-monitoring devices.

Second Place

Patel Riya, Rao Jacob, Collegiate

A Comparison Study of Porosity, Grip, and Tensile Strength of Various Filaments for Potential Use in 3D Printed Prosthetics

Manufacturers are moving away from prosthetics built with composite materials of carbon fiber, fiberglass, and resin and moving towards thermoplastic 3D-printed prosthetics. Common problems that prosthetic users face are the steep costs and the challenges of achieving a truly customized, comfortable fit. The goal of this experiment was to evaluate the performance of different types of 3D printed filaments for prosthetic use, specifically, a below-the-knee prosthetic. A porosity test was conducted to measure the internal structural density, quality, and the amount of water absorbed into each filament after a constant time interval. A static friction test was used to find the coefficient of static friction to determine the grip of each different type of filament. Finally, a tensile strength test was used to determine the maximum load the dog bone print can hold until fracturing. The following filaments were tested: PLA basic, PLA CF, PLA silk+, ABS, ABS GF, PA6 CF, PA6 GF, TPU 85A, and TPU 95A HF. The results show that the TPU 95A would make the best prosthetic as it met the criteria of gaining the least amount of water weight (due to its hydrophobic properties), maintained grip at steeper angles (due to its rubber-like properties), and resisted breakage with force applied (due to its malleability).

Third Place

Milhorn Jeremiah, Central Virginia Governor's School for Science and Technology

The Effect of Different Track Configurations (Track Radii and Bank Angles) on Biomechanical Asymmetry and its Impact on Injury.

The study's purpose was to determine if track configurations (bank angle and radii) affect biomechanical asymmetry in running. Understanding these potential biomechanical impacts would help high-performance track athletes tailor their training and racing to different track configurations and help develop adaptations needed to combat biomechanical changes. This study was conducted over four sessions, testing speeds of 6:00/mile and 4:00/mile over a 200m banked track, a 200m flat track, a 400m flat track, and a flat straight section of track. Analysis was done with Garmin Forerunner

255 data and the OpenCap 3D modeling software. The study identified 16 experimental conditions using independent variables of track configurations, speeds, and limbs. The dependent variables included hip flexion, hip abduction, ankle dorsiflexion, ground contact time, and lumbar bending. Using a Two-Way ANOVA and Tukey test with an alpha value of .05, significant differences were found in the variables hip flexion, hip abduction, ankle dorsiflexion, and ground contact time. These variables had p-values of less than .01, while lumbar bending was not significant with a p-value of .28. This study supported the research hypothesis, altering track configurations through bank angle and radius would increase biomechanical asymmetry when running in curves with lower bank angles and radii. In conclusion, track configuration had a significant effect on the variables of hip flexion, hip abduction, ankle dorsiflexion, and ground contact time. However, the study was not able to verify asymmetrical differences in turns that affect the bending of the midsection, contradicting previous research.

Honorable Mention
Josthin Mendez Merlo, Annandale High School
Forecasting Particulate Matter: An IoT and Machine Learning Approach
Background: Monitoring the ambient air quality in our surrounding environment is vital for public health, as extremely tiny particles such as PM2.5 are known as common significant contributors to respiratory and cardiovascular diseases that affect the human lungs directly. While weather stations on the internet that are considered official provide broad data, they fail to capture local specific climate data in areas near agricultural land which leads to data gaps that can't help everybody (especially individuals with asthma). The main goal for this research was to determine if a multivariate linear regression AI model paired with a custom IoT node developed using a Raspberry Pi 5 2 gigabytes, and a BME280 paired with a PMS5003, could identify and predict data with the custom modifications. **Methods:** A custom built IoT node was developed using a Raspberry Pi 5 paired with a PMS5003 laser scattering sensor, and a BME280 atmospheric sensor through I2C and UART protocols. More than 1200 rows of data were logged at 10-second intervals to capture data of the following variables: Temperature, Humidity, and Barometric Pressure; a multivariate linear regression model was built using collected and logged data. The F-statistic assured the significant relationship between the alternating data was not randomly selected. **Results**: The regression model produced a validation output of -9.798, successfully solving the unexpectedness of the hardware sensor. **Conclusion:** This research concluded that a multilinear regression model can transform a low-cost hardware into a very accurate weather station by using machine learning to overcome the physical limitation of consumer grade sensors. This study proved that applied knowledge fills the gap in what is considered performance between low-cost sensors and expensive hardware and could potentially be used to solve real world problems.

Honorable Mention
Koparde Kaeya, Mills E. Godwin High School
The Effect of Environmental Conditions on WiFi Signal Strength
The purpose of this experiment was to find the effects of environmental conditions on Wi-Fi signal strength. Technology should be perfected to minimize the

number of faults that occur. Many people enjoy listening to music, but when in an area surrounded by trees or very high up, the signal weakens. The researcher sought to determine which materials and thicknesses, when placed between a transmitter and receiver at varying distances, can most significantly hinder the signal strength. It was hypothesized that if the environmental conditions reach their worst, then the Wi-Fi signal strength will decrease. This project was conducted by building several boxes, each of different materials and thicknesses, which were placed at different distances to test the effect on signal strength. No material was the constant; wood, styrofoam, and hardyboard were used as material types, while they each had been made into boxes with thicknesses of 0 centimeter, the control, 1 centimeter, 2 centimeters, and 3 centimeters. The distances used were 0 meters, the control, 4 meters, 8 meters, and 12 meters. The results showed that when the distance and material thickness were at their highest and when the material type was the densest, the signal strength would weaken. Several t-tests were done on the data, which proved that all the data was extremely significant. The results did support the research hypothesis. In addition to the other material types and thicknesses, along with the new distance, the use of different signal wavelengths should be studied.

Honorable Mention

Sisson Spencer, Southwest Virginia Governor's School

Using an Arduino Microcontroller and Repurposed Remote-Control Car to Develop a Pacing Device for Track Athletes

Pacing is a crucial component in efficient training sessions while running. Not maintaining the desired pace can result in a session not producing the desired outcome for the runner. Exceeding the desired pace can cause overexertion leading to a poor session and possible injury. However, runners often don't have a visual guide to assist them in pacing around a track. A device was developed to aid runners in pacing through allowing them to insert a desired pace to set the speed of the device while guiding it manually. The device utilized a ECX Ruckus remote controlled car. The car's body, electronic speed controller, remote control receiver, remote control transmitter, drive motor, and steering servo motor were all repurposed to create this device. A number pad was added as well as an Arduino Nano clone (Elegoo Nano) that allowed the device to be programmed. The device was tested for various paces over 150 meters to find error means based on the difference in expected and recorded times. These means were compared in an ANOVA test where the null hypothesis stated that all error means were equal and the alternative hypothesis stated that some pair of means was unequal. The resulting p-value was found to be <0.0001, meaning the null hypothesis was rejected. This meant the device was unable to travel at every desired pace entered by the user. The findings of this project can be expanded on to create a device that will traverse the line of a track autonomously while traveling at specific desired speeds with a more precise electronic speed controller.

Okes Logan, Central Virginia Governor's School for Science and Technology

What is the most efficient power source with minimal pollution and best production capacity?

The purpose of this research study was to identify, with existing data, what the most efficient source of power generation is through three main factors. This study took place online from November-December 2025 using certified websites that dealt with power across the world. Four types of power production were examined: fossil/coal, nuclear, wind, and solar. United States data was used as the baseline. Fossils had the most with 10434 followed by nuclear with 2686 then wind at 2304 and finally solar with 1631. Next pollution on average in terms of CO2/KWH in grams per producer. Results of this are as follows, fossil with 900, solar with 50, nuclear with 27.5, and wind at 10.5. The production capacity of sources concluded with fossils at 0.76, nuclear at 1.1, wind at 45, solar at 360 in terms of square miles per 1000Mw. The percent power make-up of four other countries was also examined for a general overview. Three other countries, that being China, EU, India were examined to see the percent make up of each alternate power source in the country. Qualitative data provided some statistical information that made a comparison between sources and states. My hypothesis of nuclear being the most effective was partially supported as some evidence counters this claim. Overall, the study suggests renewables are the future, especially nuclear, but a deeper dive into the production and state development index to power production relation could be studied for a better understanding of power production and use.

Neuman Hayden, Mills E. Godwin High School

The Effect of Heat Sink Material on Heat Dissipation Efficiency

The purpose of this experiment was to investigate the effect of various heat sink materials on heat dissipation efficiency. Heat sinks are present in every electronic device today, and they are the reason that our devices don’t overheat. The most common heat sink materials include aluminum, graphene-coated heat sink, and copper. In this experiment, heatsinks made of each of these material compounds were placed over a heat source. Then they were heated for five minutes, and their temperatures were taken every minute. The control in this experiment was no heatsink and just the direct heat source. A hypothesis was written that if different heat sink materials were tested for heat dissipation efficiency, then the aluminum heat sink would have the best heat dissipation efficiency. This hypothesis was formulated from online research that was conducted before this experiment, which found aluminum to be the most used heat sink material. Similarly, the results of this experiment indicated that aluminum was the most effective heat sink material for heat dissipation efficiency. A t-test was conducted on the data and showed that the data was significant for aluminum vs. control, graphene-coated heat sink vs. control, copper vs. control, aluminum vs. graphene-coated heat sink, and aluminum vs. copper, but was not significant for graphene-coated heat sink vs. copper heat sink. The results supported the research hypothesis, showing that aluminum is the best heat sink material for heat dissipation efficiency. This research could be expanded further by experimenting with the temperature of the heat source, the size of the heat sinks, or the weight of the heat sinks.

Environmental & Earth Science - A (ENV-A)

Bethel Award
First Place
Cooke Olivia, Chesapeake Bay Governor's School *Comparative Study of Catch Efficiency and Fouling Accumulation Between Galvanized and Vinyl-Coated Crab Traps*

Blue crabs are both economically and culturally important to the Chesapeake Bay region, yet little research has compared the effectiveness of different crab pot materials commonly used by local watermen. This study examined the differences in catch efficiency and fouling accumulation between galvanized wire and vinyl-coated crab pots in order to determine which type is more suitable for small scale commercial operations that manually pull their pots. Twelve identical pots, six galvanized and six vinyl-coated, were used in Rosier Creek near Colonial Beach, Virginia, from May 24, 2025, to August 4, 2025. The pots were checked every two to three days for a total of 26 sampling days. Data collected included number of sellable crabs, pot weight, visual fouling coverage, water temperature, and salinity. Statistical analyses were then conducted using ANOVA tests. Results showed that vinyl-coated pots caught significantly more sellable crabs than galvanized pots, producing a statistically significant p-value of 0.00054. However, vinyl-coated pots also accumulated significantly more fouling and weight over time, with statistical analysis producing a p-value of 6.78×10^{-99}. The increased weight suggests greater physical labor demands for crabbers who manually pull their pots. These findings demonstrate a tradeoff between higher catch efficiency and increased physical workload and cost. The results provide crucial insights for small scale Chesapeake Bay watermen who must balance profitability, equipment costs, and labor demands when selecting crab pot materials.

Second Place
Chari Aneesha, Mills E. Godwin High School
The Effect of Magnetism on the Phytoextraction of Lemna minor

The purpose of this experiment was to find the effect of different levels of magnetism on the phytoextraction of *Lemna minor*, also known as duckweed. In wastewater treatments, duckweed has been utilized in bioremediation. Enhancing their phytoextraction efficiency with magnetic fields aims to improve water quality and prevent disease in communities. *L. minor* was placed in copper sulfate solutions and exposed to either one, two, or three magnets. Duckweed exposed only to the geomagnetic field acted as the control. The absorbance of the solutions was measured before and after the four-day exposure period. It was hypothesized that solutions treated with two magnets would have the greatest decrease in absorbance. While the control resulted in an increase, the solutions treated with magnets resulted in decreases, with three magnets having the largest decrease of 0.282 Au.
Consequently, the results did not support the research hypothesis. Six t-tests were performed on the data, confirming that most of the data for magnetism influencing phytoextraction were statistically significant. However, the data for one vs. two magnets were not statistically significant. It is believed that the results are due to the fact that three magnets altered cell membrane structure and increased antioxidant

enzyme content to improve permeability and the stress response for efficient phytoextraction. This research provides a foundation for further studies to investigate the effect of magnetic fields on other hyperaccumulator plants under different environmental stressors.

Third Place

Nguyen Rebecca, Chesapeake Bay Governor's School

A Comparison of Phragmites Reeds and Cordgrass Reeds as Nesting Material for Solitary Bees

Solitary bees, containing species of leafcutter bees (*Megachile spp.*) and mason bees (*Osmia spp.*), have been in a decline for the past decades due to loss of habitats that prevents them from laying eggs. Due to them being pollinators for gardens and crops, gardeners and farmers have been trying to raise their numbers. The tall marsh grass Phragmites (*Phragmites australis*) has been used for nesting reeds to occupy the bees, but its status as an invasive species makes it problematic to use because of its effect on the environment; conservationists would like to get rid of it. In this study, reeds of the native big cordgrass (*Spartina cynosuroides*) were used as a comparison to see if solitary bees would prefer it more than phragmites. Over the summer, a study was conducted with leafcutter bees to look for a strong preference in nesting material between cordgrass and phragmites reeds. The study found that cordgrass had a higher number of capped reeds than phragmites by a small difference. As a result, cordgrass could substitute for phragmites in reed material to provide solitary bees a nesting place. It would allow removal of phragmites without any disruptions to the solitary bees' growth.

Honorable Mention

Abid Safwan, James Kim, Osbourn Park High School

Design and Performance Analysis of Low-Cost Lead Filtration Systems

Lead toxicity is an important environmental issue and a major global challenge, particularly in developing countries where water contamination can pose serious health risks. Heavy metals contaminate drinking water through pipe corrosion. Long-term exposure to such harmful elements can cause damage to many parts of the body, including nervous system defects, increased risks of cancer, and lower cognitive function. While commercial filtration systems do exist, they are often too expensive for widespread use, especially in low- and middle-income countries. This project expands upon the findings of previous experimentation, showcasing effective methods of lead filtration. These methods were further investigated and engineered into an accessible filtration component designed for use in standard water systems. The prototype filters were required to maintain a production cost under $10 for affordability while effectively filtering at least 97% of heavy metal solutions to be considered functional. They were also designed to withstand standard water pressure (40 psi-80 psi) and operate without the need for thermal or electrical energy. Iron solutions of 100 mg/l were made to replace previously tested lead solutions. Each prototype underwent ten trials using 1.0 gallon (3.79 liters) of iron solution per test before measuring iron concentrations to assess performance. Experimental results indicate that the constructed ion exchange filter holds the strongest potential to effectively filter heavy metals while maintaining

affordable production costs, successfully reducing iron concentrations to nearly 0 mg/L. These findings offer a potential solution to addressing global public health issues and improving access to clean water.

Honorable Mention

Bansal Reya, Mills E. Godwin High School

The Effect of Biochar Concentrations on UVB Blocking Efficacy

In response to growing environmental concerns regarding plastic waste and the need for food preservation efforts, this study was conducted to investigate the efficacy of various biochar concentrations against ultraviolet-B (UVB). UVB radiation is a catalyst for photo-oxidization and nutrient degradation in food, thereby fostering the development of biodegradable shields. UVB blocking was determined through the casting and testing of polymer films created with agar-agar powder and varying concentrations of biochar powder under UVB radiation. UV blocking capacity was measured with a decrease in radiation transmittance using a UVB meter. The control was no biochar to provide a baseline as to how agar demonstrates UVB blocking properties. It was hypothesized that films with 10% biochar will have the greatest blocking performance. It was found that the addition of biochar in the polymer films increased the UV blocking capacity, especially at higher concentrations. The 10% biochar loading in the films were able to block 97.7% of UVB radiation, nearly a 4% increase from films incorporated with no biochar (0%). A t-test was done on the data, revealing all data was significant, and therefore, the results did support the research hypothesis. This study revealed the impact of biochar's properties on enhancing UV blocking characteristics of polymer films. The greater concentration incorporated into the films increased the density of the carbonaceous particles and decreased UV penetration through the film. Furthermore, this research has demonstrated how biochar's porous structure has the potential to serve as biodegradable and sustainable UV shields for food packaging applications.

Honorable Mention

Pham Abby, Khan Anusha, Nkhoma Mlinda, Governor's School @ Innovation Park

From Trash to Treasure; Repurposing Silk Sericin into a Durable Cross-Tissue Healing Biomaterial

Background: Sericin is a natural, bioactive protein found in silkworm cocoons, known for its biocompatibility, anti-inflammatory, and wound-healing properties. Despite its medical potential, due to limiting factors such as rapid degradation, high reduction levels of the sericin caused by high temperature is largely discarded as industrial and textile waste because of its extremely unstable structure. High extraction temperatures ultimately degrade its structure, leading to poor mechanical strength and rapid dissolution within water. This study aims to divert this protein away from being discarded as "waste" from the environment and towards stabilizing it into a biomaterial through the addition of sustainable polymer crosslinkers. **Methods:** To extract the sericin, the silkworm cocoons were degummed, and this experiment used calcium lactate to form the gels. Additionally, for the sericin-alginate hydrogels, a 1% w/v amount of alginate for every 30 mL of sericin was used and placed them into petri dishes to crosslink. Along with this, a 4% w/v of sericin-alginate was used for every 1% w/v of

glycerol to have a balanced ratio. Once the polymers were crosslinked, they were tested using the Thickness Test and the Swelling Ratio Test to test the mechanical strength and moisture retention of the sericin solutions. **Results:** Quantitative analysis revealed that the sericin-alginate glycerol, compared to the other hydrogels tested, significantly outperformed the raw sericin. While the sericin alone lacked the structural stability needed to maintain shape, the addition of the alginate and glycerol provided the reinforcement needed to its structure in order to be used in medical applications. The glycerol-enhanced hydrogels showed the highest stability, though the standard sericin-alginate also performed significantly well, emphasizing that the secondary polymers added affectively compensated for sericin's natural structural weaknesses. **Conclusions:** This research exemplifies that with targeted crosslinking, utilizing alginate and glycerol, sericin can be transformed from a problematic industrial byproduct into a thriving, high-performance biomaterial. All in all, since sericin does not have the structural integrity to hold itself alone, its performance can be maximized through sustainable polymer additives, such as alginate and glycerol, providing a blueprint for reducing textile waste while creating eco-friendly, biodegradable solutions for the medical industry, and more so, for the environment.

Dove Autumn, Chesapeake Bay Governor's School

The Power of the King: How King Tides Effect Nutrients and Bacteria Levels Along the Coast

King tides, the highest astronomical tides that occur when lunar and solar gravitational forces align, are becoming increasingly impactful as sea levels rise. These extreme tidal events can inundate low-lying coastal areas and potentially transport nutrients and microbial contaminants from land into nearby waterways. This study investigated whether nitrogen, phosphorus, total coliform, and Escherichia coli (E. coli) levels differed between king tide flooding conditions and non-flood conditions in the Potomac and Rappahannock Rivers along Virginia's Northern Neck. Water samples were collected prior to a king tide event (October 8, 2025) and during peak king tide flooding (October 10–12, 2025). Nutrient concentrations were measured using Chemetrics spectrophotometric methods, and bacterial colonies were quantified using Coliscan. Paired t-tests were conducted to determine statistical significance between flood and non-flood conditions. Results indicated a statistically significant increase in phosphorus levels ($p \approx 0.02$) during flooding, while nitrogen showed no significant difference ($p \approx 0.4$). Total bacterial colonies significantly increased during king tide flooding ($p \approx 0.049$), and E. coli colonies showed a substantial but not statistically significant rise ($p \approx 0.1$). These findings suggest that king tide flooding may act as a non-point source contributor of phosphorus and microbial contamination in coastal systems. Understanding these nutrient and bacterial fluxes is essential for improving coastal management strategies and protecting both ecosystem and public health as sea-level rise intensifies tidal flooding events.

Headley Sean, Chesapeake Bay Governor's School

The Impact of Solar Farm Distance on Zinc Concentrations in Private and Public Water Supplies

The rapid development of solar power infrastructures has triggered various concerns about their environmental effects, such as the heavy metal contamination of water sources. This study examined whether adequate zinc levels in private and public water supplies can be linked to the closeness of big solar farms in six rural areas of Virginia's Northern Neck and Middle Peninsula. Samples of water (n = 33) were taken from wells and municipal water sources at solar farms that varied from 54 to 920.5 meters from solar farms. The levels of zinc were determined by a colorimetric zinc test kit of CHEMetrics and spectrophotometric at 620 nm. The Zinc Levels were compared by locations, and a linear regression analysis was used to determine whether the results were significant statistically. Almost all zinc concentrations were less than 2 ppm with a few exceptions greater than 5 ppm, the limit that can cause health effects. In addition, some of the shallow wells situated closer to the solar farms had a little higher zinc concentration, however, the regression analysis showed that the relationship between the variable zinc concentration and the distance to the solar farms was not statistically significant ($p = 0.242$). Thus, these findings align those of the null hypothesis and imply that solar farm proximity alone is not a reliable indicator of zinc contamination. However, occasional elevated readings and higher averages in shallow wells highlight the importance of continued environmental monitoring as solar infrastructure expands.

Wallace Chase, Chesapeake Bay Governor’s School

A Study of Coastal Flooding Events in Virginia

The rise of sea levels caused by climate change is leading to higher flooding that is creating more problems in the coastal Mid-Atlantic area. Their low-lying location exposes communities along the Chesapeake Bay to nuisance high-tide flooding, king tides, and storm surge due to subsidence and the destruction of natural barriers, such as wetlands. The paper explores the variations in flooding frequency and tidal height in three tide-gauge stations within the bay: Sewells Point, Windmill Point, and Lewisetta, Virginia. The data obtained at NOAA Tides and Currents was used to analyze these sites at a combination of 3.0 feet mean low lower water level. The synthesis examines the high tides exceeding these thresholds in 2004, 2014, and 2024. Verified and predicted king tides and storm surge heights are also compared in this synthesis. indicated that there was growth in high tide events above 3.0 feet at all three locations. This suggests that there is a rise in the frequency of floods, although other extreme weather conditions like king tides and storm surges did not change significantly. Measured king tide and storm surge heights were consistently higher than the estimated elevations at all locations. Nevertheless, a greater sample size is required to identify the trends in the interannual variability of flooding. Other studies and predictive models have shown increased vulnerability to coastal areas like the Chesapeake Bay, showing possible increases to water levels of 0.8 feet to 1.6 feet by 2050. These rising sea levels have caused problems like eroding shorelines, damage to property, and retaining saltwater, and will only get worse with increasing sea levels. This study emphasizes the significance of citizen science initiatives like the Catch the King program, which enhances predictive models to aid in planning, provides evidence for the need for coastal infrastructure changes, and informs local policy makers, allowing them make more informed decisions during emergencies, as more flooding will cause financial strains on both citizens and nations.

Pradeep Dyuti, Mills E. Godwin High School
The Effect of Ozone Exposure on Moisture Loss of Skin

This experiment aims to educate on how skin moisture is affected by ozone exposure. Air pollutants are often overlooked in relation to skin damage. With constant exposure, severe skin diseases and irreparable damage could occur. Ozone is a prominent pollutant that is immensely helpful in the stratosphere, but harmful in the troposphere. The experiment conducted tested the effect of ozone on hydrogel sheets, acting as skin, to test moisture loss. They were put under the ozone for different amounts of time: zero minutes, fifteen minutes, thirty minutes, and sixty minutes, and tested to identify the change in moisture content. The hypothesis stated that if the time of ozone exposure increases, then the moisture loss would also increase. This was shown to be supported by the data, as the moisture loss increased through each experimental group, and there were great differences between the data. The standard deviation calculated indicated that the data was precise due to the low numbers. There were three t-tests conducted, of which two came out to be significant, and one was insignificant and due to chance. This shows that the overall experiment was significant, and the null hypothesis was rejected. The main reasoning for the results was the effect of ozone on the outer layer of the skin, the epithelial layer, or, in this case, the hydrogel sheets. Other factors were the room temperature and setup beforehand, which were both human errors. For further research, both the methods of pollution protection and other pollutants should be investigated.

Environmental & Earth Science B (ENV-B)

First Place
Khan Luqmaan, Mills E. Godwin High School
The Effect of Climate Variability on Malaria Prediction in Nigeria

This study investigated the effect of climate variability on malaria incidence in Nigeria by examining mosquito egg hatch rates under controlled environmental conditions and applying climate based predictive modeling. The purpose of the study was to determine whether temperature and humidity significantly influence mosquito reproduction and malaria risk. It was hypothesized that moderate temperature and humidity levels would result in higher mosquito egg hatch rates and stronger malaria prediction accuracy. A laboratory experiment was conducted using *Anopheles gambiae* eggs exposed to varying temperature and humidity levels across 25 repeated trials per condition. Descriptive statistics and independent sample t tests were used to analyze the experimental data. Climate variables were then evaluated using receiver operating characteristic analysis to assess predictive accuracy for malaria incidence in Nigeria. The results showed statistically significant differences across all conditions and a high area under the curve value, supporting the role of climate variability in malaria transmission.

Second Place
Ward Ella, Chesapeake Bay Governor's School

Build, Code, Deploy: Using a DIY Ultrasonic Water Level Sensor for High School Citizen Science

Monthly spring tide and annual perigean tidal flooding, or “sunny day flooding” is a major negative effect of rising sea levels which heavily impacts low-lying coastal areas, such as Mathews County, Virginia. The purpose of this project is to test the claim, from scientists at the University of North Carolina Wilmington, that a high school student can successfully build, code, and deploy a UWL Sensor independently. Using instructions on the UNCW GitHub and the IORodeo site, the UWL Sensor was constructed by the high school researcher. Once built and programmed, the UWL sensor was deployed to compare the UWL sensor data to standard data collected by NOAA’s Yorktown USCG tide station. The UWL Sensor was deployed in the field on October 9th, 2025, at William’s Wharf in Mathews, Virginia, where it collected distance data, stored it to an SD card, which was collected on October 17th, 2025, for the first sampling period. The UWL Sensor data and NOAA Yorktown USCG Station aligned both in time and tidal amplitude. A t-test between the higher high-water values from both data sets showed no statistical difference, $p>0.05$, between the time of high tide that the UWL Sensor showed and the time of high tide for the NOAA Yorktown USCG Station. For this proof-of-concept study, the UWL Sensor was successfully built and deployed by a high school student and has functioned correctly for weeks at a time running on its solar power system. As global warming increases sea level rise and tidal flooding, Virginia's coastal communities and cities, such as Norfolk, are being affected and being slowly inundated. It is essential that scientists and citizens continue working together toward ways for citizens to prepare for the damage that come with tidal flooding, and the UWL Sensor is a good first step in the direction of a solution.

Third Place

Coghill Madison, Central Virginia Governor’s School for Science and Technology

The Effect of mycorrhizae on Glycine max Drought Avoidance

The purpose of this study was to determine if the presence of mycorrhizae increased drought avoidance within *Glycine max* through enhanced communication between rhizospheres. In order to create this connection, two pots were conjoined with mesh to prevent roots from passing through but allowing for mycorrhizal colonization. Germinated plants were then assigned to drought groups. After the growing period, plants were cut at soil-level and weighed to be able to calculate water weight. First, a two-factor ANOVA was performed upon the fresh-cut weights of the plants in which there was a significant p-value of .01 ($a = .05$). A post-hoc Tukey test was conducted to further determine the effects of the droughts on the plants. After water weight was calculated, a two-way ANOVA was run, gaining a p-value of .01, followed by a second post-hoc Tukey test where it was determined that most of the significant values lied within the severe drought groups. Finally, a t-test was conducted against the single plant group and the duo-plant groups, determining differences with both severe groups as well as the moderate group with mycorrhizae presence. After analyzing the data, it was found that it supported the hypothesis that mycorrhizae have a positive effect on water retention in non-droughted plants in response to drought communication. These findings open questions for further research into hormone communication and the

possibility of this happening directly between rhizospheres, as well as opening a pathway for a non-artificial safety net regarding drought in agriculture.

Honorable Mention
Baxter Caitlyn, Central Virginia Governor's School for Science and Technology
PFAS Levels in Virginia Surface Water: Location, EPA Regulations, and Testing Agency Comparisons

The purpose of this research was to compare levels of Per- and Polyfluoroalkyl Substances (PFAS) within the selected region of Virginia at highway, airport, and rural locations; to determine if the levels of PFAS were higher than the Environmental Protection Agency (EPA) regulations; and to discover if the sites tested had higher levels of PFAS than what had been previously reported. Three samples of water were taken at the sites of previous Virginia Department of Environmental Quality (VDEQ) test locations: a highway, an airport, and a rural location, using the Cyclopure Water Test Kit for PFAS. Additional data was acquired from the VDEQ Statewide PFAS Sampling Dashboard. A single-factor ANOVA test, with the alpha set at .05, revealed the levels of PFAS at different locations were not statistically significantly different with a p-value of .85. Five one-sample T-tests revealed the levels of PFAS within the region were statistically lower than the EPA regulations; each had a significant p-value of .01. A paired T-test revealed the Cyclopure test results were statistically lower than the VDEQ data with a significant p-value of .01. Despite seeing statistically significant differences, none of the research hypotheses were supported. The levels of PFAS in this study did not differ based on sample location. Environmental monitoring and EPA regulations are crucial for minimizing PFAS levels. Routine testing for PFAS and universally accepted Maximum Contaminant Levels (MCLs) are necessary because PFAS exposure has been linked to negative health effects; some long-term health effects aren't fully understood yet.

Honorable Mention
Gutta Jeevan, Mills E. Godwin High School
The Effect of Different Aquatic Plant Species on Phosphorus Removal

Excess phosphorus pollution is a major contributor to freshwater eutrophication and declining water quality. This study investigated the ability of three native aquatic plant species, *Elodea canadensis*, *Vallisneria americana*, and *Ceratophyllum demersum*, to remove phosphorus from water using phytoremediation. Each species and a no-plant control were exposed to a 0.5 ppm phosphorus solution for one week. Phosphorus concentrations were measured before and after exposure to determine removal effectiveness. Results indicated that all plant species reduced phosphorus levels compared to the control, with *Elodea canadensis* demonstrating the greatest phosphorus removal. These findings support the use of native aquatic plants as natural, cost-effective tools for improving freshwater quality.

Honorable Mention
Sterling Hudgins, Chesapeake Bay Governor's School
Examining Cooling Effectiveness and Aesthetic Value of Vertical Greenery Systems

Green Design minimizes environmental impact by creating efficient and resourceful building systems. Green Walls are vertical built structures that house vegetation; there are two primary types of Green Walls: Modular Green Walls (MGM) and Green Facades (GF). MGW uses stacked modules with potted plants; GF uses a planter and a supporting structure for upward plant growth. To test the cooling effects of MGW compared to GF and a brick wall control, each wall type was manufactured then mounted on the exterior of a public brick walled building in the town of Mathews VA, Plants were potted into the wall treatments in May, 2025 and thermometers were placed behind each green wall treatment and on the Brick Wall control (BW) that recorded temperatures at 12:00 pm daily from July 24 to November 20, 2025. The MGW cooled the adjacent building wall by an average of 30.9% and the GF cooled the adjacent building wall by an average of 6.6%. A statistical t-test showed the MGW's cooling effect was statistically significant relative to the BW control ($p<<0.05$); the GF cooling effect was only significant ($p=0.0038$) for July and not significant thereafter. A survey published on social media asked the local public who had seen the walls, to rank the MGW, GF, and BW based on their aesthetic value. The survey resulted in 139 responses selecting the highest aesthetic value over the treatments, 84% of respondents chose MGW; 15.2% chose GF; and 0% selected the BW. The results of this experiment show that green walls hold high aesthetic value and MGW are the most effective treatment. Green design is the proactive approach we need for our future that simultaneously reduces energy cost and enhances our wellbeing and environment.

Patel Dhilan, Mills E. Godwin High School

The Effect of Different Soap Types on Oily Feathers

The purpose of this study was to determine which soap most effectively removes oil from bird feathers while causing the least amount of damage. Oil spills impact seabirds by reducing waterproofing, insulation, and flight ability. Wildlife rescue organizations clean oil-covered birds safely and efficiently, making it essential to identify the most effective cleaning agents. This experiment compared four commonly used dish soaps including Dawn, Palmolive, ECOS and Seventh Generation to evaluate their effectiveness in removing oil. The null hypothesis stated that soap type would have no effect on the cleanliness and condition of oil-coated bird feathers, while the research hypothesis predicted that Dawn would remove the most oil while causing the least damage. Dawn was used as the control because it is the current standard used by wildlife rescue organizations. One-hundred feathers were divided among four soap types. All feathers were coated in an oil-based food coloring mixture for twenty-four hours and then cleaned under identical conditions. After drying, feathers were rated on a cleanliness scale from 1 (dirtiest) to 3 (cleanest). A chi-square test was conducted at a 0.05 level of significance to analyze differences among soap types. The results showed statistically significant differences between soaps, leading to the rejection of the null hypothesis. Dawn was the most effective soap overall, followed closely by ECOS, while Palmolive and Seventh Generation showed lower overall effectiveness. This supports the hypothesis that Dawn is the most effective soap for cleaning oily bird feathers and provide valuable insight for wildlife rescue efforts following oil spills.

Purcell Jack*, Comparative Evaluation of Household Filtration Materials for Emergency Water Treatment: Turbidity, Reduction, Efficiency, and Practical Application*

Severe weather or failures in water treatment systems can make tap water unsafe to drink. In January 2025, a winter storm disrupted water treatment operations in Richmond, Virginia, leaving residents without safe drinking water and highlighting the need for practical at home water treatment options. This study evaluated five household filtration materials as pre-treatment steps before chemical disinfection to compare reduction in turbidity and efficiency during emergency situations. The materials tested were paper towel, cotton cloth, coffee filter, sand/gravel filtration, and a layered combination filter. Water was collected from the James River had an initial turbidity of approximately 40 NTU. Each filtration method was tested three times. Turbidity reduction percentage, filtration time, and water yield percentage were recorded. An efficiency score was calculated using the formula: Efficiency = (Turbidity Reduction (%) × Yield (%)) / Filtration Time (seconds). Sand/gravel filtration achieved the highest turbidity reduction (approximately 62%) but required the longest processing time (approximately 925 seconds per 500 mL). Paper towel filtration reduced turbidity approximately 17% with fast processing (approximately 33 seconds per 500 mL) and high yield (approximately 93%), resulting in the highest efficiency score. The hypothesis that coffee filter filtration would be the most efficient was not supported. After filtration, all samples were treated with chlorine dioxide tablets and bacterial testing showed all treated water reached safe levels. These findings suggest that common household materials can effectively filter water during emergencies and the best filtration method depends on whether speed or water clarity is more important.

Blair Julie*,* Central Virginia Governor's School for Science and Technology
Evaluating the Phytoremediation Process of Elodea and Excess Iron in Fresh Water Systems

The purpose of this experiment was to evaluate the potential of elodea, a freshwater plant, in improving the environment by using technological tests to see the change in iron levels in water. In this experiment, six 1.5-gallon tanks with 1 gallon of water and equal amounts of elodea plants in each. The tanks were separated into three groups. The iron levels were tested from a local access of the James River using a spectrophotometer, for a baseline. Iron filings were added to the groups of tanks to create simulated levels of exposure: 0.0588g to the control, 0.0785g to the low concentration, and 0.1137g to the high concentration. Every weekday for 14 days, the light absorbance of the water for each tank was tested using a spectrophotometer. There was no significant difference in the change over time of the High ABS of each group (ANOVA p-value = .12, alpha = .05). There was a significant change in the High ABS of each group through the Linear Regression (p-value < .01, alpha = .05). These findings did not support the research hypothesis that if there is an excess amount of iron in water, then elodea plants will intake more iron. This research shows that elodea is effective for phytoremediation and could be a beneficial way to mediate the excess iron pollution in our local freshwater systems.

Stahl Avery*,* Chesapeake Bay Governor's School
A Survey of the Copepod Population in Urbanna Creek During Summer of 2025.

Copepods connect phytoplankton primary producers in the food web to the larger fish higher up in the food web which are the foundation of the higher productivity of the ecosystem. Fluctuations in secondary production by copepods could be a significant reason why larger fish populations are decreasing, because fish larvae must have enough planktonic food at the right times in their life history to survive and reach maturity. Overall, the copepod population abundance is a function of how much phytoplankton they are able to consume in the spring season. In a two tailed t-test of the sampled nauplii and calanoids, it was found that p=0.95, which means that it is statistically likely that the nauplii in Urbanna Creek will mature into Calanoid copepods through these later summer months. The connection that copepods provide to the food web is invaluable, but not only is this important in the Chesapeake Bay, but also incredibly important in other areas, including the coast of Peru, California, and Chile, where upwelling occurs, as well as our local coastal ocean. According to the match-mismatch hypothesis, if an increase in population of prey animals, in this case copepods, matches the breeding period of their predators, their predators will become more successful, and their populations will increase much more than if their breeding times are mismatched, or at widely different times.

Johnson Logan, Chesapeake Bay Governor's School
The Effect of Atmospheric Conditions and Habitat Type on Ruby Throated Hummingbird (Archilochus colubris) Feeding Frequency

Over the years, Earth's climate has experienced vast environmental changes in response to global warming. As atmospheric conditions change, organisms and ecosystems are forced to adapt. Among these species is the Ruby Throated Hummingbird (*Archilochus colubris*). Since 2004, their population has experienced a decline across Central and North America; it is speculated that this is due to global warming (English et al., 2021). This study aimed to discover the effect of atmospheric conditions and habitat type on the feeding frequency of Ruby Throated Hummingbirds. Feeders were set up and monitored by motion sensor game cameras in three habitats: residential, forest clearing, and forest. For 29 days during an Eastern Virginia summer, hummingbird visits were recorded. It was revealed that atmospheric conditions and habitat type uniquely influence hummingbird feeding frequency. It cannot be determined from this study if global warming is the driving cause for Ruby Throated Hummingbird population loss, but the results indicate that global warming will continue to impact their behavior and energy expenditure and needs.

Speleological Society Award

Das Subhransu, Mills E. Godwin High School
The Effect of Geographical Location on Near-Future Earthquake Frequency

This study researched the effect of geographic location on the frequency of near-future earthquakes with a magnitude of ≥4.0. A hypothesis was made that Indonesia, which is located along active tectonic plate, would experience the greatest number of earthquakes. Earthquake data was collected from the United States Geological Survey (USGS) catalogs covering the years 2014-2024. Four different geographic regions were analyzed such as Japan, Indonesia, Chile, and California, with 25 trails included for each region. The dependent variable was the count of earthquakes with magnitude

≥4.0, and constants included the time window, data source, and minimum magnitude threshold. Because earthquakes are natural events that cannot be experimentally controlled, there was no control group, but an observational design was used to compare the earthquake data. Statistical analyses showed that regions located along active plate boundaries showed higher average earthquake frequencies such as Indonesia. California showed the least average frequency among the regions studied. Furthermore, comparisons showed significant differences in earthquake frequency between regions. Overall, the results support the hypothesis and showed that geographic location impacts earthquake frequency. These findings show the role of tectonic plate activity in earthquake patterns and show geographic factors in earthquake risk preparedness.

Beavers Claire, Mills E. Godwin High School
The Effect of Fountains on Lake Oxygenation

The purpose of this experiment was to find the effect of fountains on lake oxygenation. In some lakes, fountains are used to help keep the oxygen level in the lake higher and this experiment tests whether the difference is significant. Lakes with and without fountains were tested for their water oxygen percentages. The control of this experiment was the lakes without fountains. It was hypothesized that lakes with fountains would have a higher oxygen percentage than lakes without fountains. The results showed that lakes without fountains had oxygen levels about 3 percent higher than lakes with fountains. A t-test was done on the data, and it showed that the oxygen percentage in lakes without fountains was significantly higher than in lakes with fountains. The results did not support the hypothesis.

Environmental & Earth Science C (HS ENV-C)

First Place
Guduru Aarushi, Mills E. Godwin High School
The Effect of Phytoremediator Plants on Motor Oil Spills in Fresh Water

The objective of this experiment is to identify the most effective phytoremediator plant to reduce Chemical Oxygen Demand (COD) in motor oil-polluted water. Motor oil has become a widespread pollutant in freshwater systems. Despite its prevalence as a pollutant, many traditional remediation methods are either ineffective or leave the water unfit for other uses. However, phytoremediation, the use of green plants to absorb pollutants, offers a more sustainable and environmentally friendly alternative. Three different plant species were chosen: Water Hyacinth, Water Lettuce, and Water Spangles. Each group was treated with 75 mg/L of motor oil and 1025 mL of water, and the COD was measured every 5 days for a total of 25 days. The independent variable group with no plants acted as the control. It was hypothesized that Water Lettuce would present the greatest reduction in COD levels. In support of the research hypothesis, data gathered revealed that Water lettuce shows the greatest change in COD levels. T-tests showed this reduction was significant when comparing Water Lettuce to Water Spangles, Water Hyacinth, and the control. However, Water Hyacinth vs Control, Water Spangles vs Control, and Water Spangles vs Water Hyacinth proved not significant.

The effectiveness of Water Lettuce may be due to its production of numerous antioxidants, such as ascorbic acid and phenolic compounds, which could aid in reducing COD. This research could lead to further studies investigating the amount of motor oil in which Water Lettuce is most effective, and other aquatic phytoremediator plants, such as duckweed.

Second Place

Gammill Esther, Mathematics and Science Academy at Ocean Lakes High School

Halophyte Intercropping for Saline Agriculture

Halophyte intercropping is a potential solution for coastal agriculture affected by saltwater intrusion; this is a practice where salt-tolerant plants (halophytes) are planted in between crops such that the halophytes uptake the salt instead of the crops. Thus, the research explored the potential of halophyte intercropping applied to coastal agriculture with respect to *Solanum lycopersicum* and *Sesivum portulacastrum*. 1 pan was filled with soil and 4 *Solanum lycopersicum* plants, watered with tap water. A second had saline soil with 4 *S. lycopersicum* plants, watered with salt water (electrical conductivity of 8 dS m-1). The third and fourth pans had saline soil, 4 *S. lycopersicum* plants, and 4 *Sesuvium portulacastrum* plants, watered with the same EC of salt water. Height measurements, observations, and photos were recorded. All tomatoes in the first pan grew well with heights hardly changing, while the second pan's average height was 37.67% of its peak height, the third pan's average height was 0.00% of its peak height, and the fourth pan's average height was 29.56% of its peak height after 23 days. The tomatoes in the 2nd-4th pans wilted and shriveled in most cases though with attempted growth. The tomatoes intercropped with the *Sesuvium portulacastrum* did not fare any or significantly better than those without *Sesuvium portulacastrum* with saltwater. The results conclude that halophyte intercropping with respect to *Solanum lycopersicum* and *S. portulacastrum* is largely unsuccessful but would benefit from further experimentation, like placing the tomatoes closer to the roots of the *Sesuvium portulacastrum*.

Third Place

Tao-Lin Milo, Blacksburg High School

Investigating the Effect of the Number of Predictor Locations and Predictor Location Concentration on LSTM Precipitation Dry/Wet Hour Classification

Precipitation forecasting is an important task. To help enhance accuracy, a variety of methods have been proposed, including deep learning methods. In this study, the effects of the number of predictor locations and the concentration of those predictor locations in the precipitation forecasting performance of LSTM models were assessed. Specifically, the task of wet/dry hour classification was attempted, utilizing the F1 score as a performance metric for the trained models. The trained models showed a substantial improvement over random guessing, often achieving F1 scores in the 0.6 to 0.65 range compared to around 0.2 for random guessing. The incorporation of a few additional predictor locations was found to be effective in enhancing F1 scores, albeit by a small amount. Beyond the incorporation of 3 extra predictor locations, however, the effects of further increasing the number of predictor locations or altering the concentration of the predictor locations were not practically significant. Several

limitations include the use of reanalysis data and the small size of the models and datasets. Addressing such limitations and improving the models could be possible paths of future inquiry.

Honorable Mention

Patel Aarya, Clover Hill High School

The Effect of Types of Plants in a Room, When Volatile Organic Compounds (VOC) Are Released, on the Amount of VOC Present in the Room, Over Time, Displaying what Type of Plant Removes the Most VOC.

The purpose of this study was to determine the efficacy of various indoor plant species in reducing the concentration of Volatile Organic Compounds (VOCs) within an enclosed environment. It was hypothesized that if exposed to VOCs, the *Epipremnum aureum* (Pothos) plant would remove a higher concentration from the air than other species due to its high adaptability and leaf surface area. Six plant species, Dracaena, English Ivy, Spider Plant, Peace Lily, Snake Plant, and Pothos, were tested across 17 trials per level. Each plant was placed in an individual airtight greenhouse chamber. A baseline VOC measurement was recorded in parts per million (ppm) using a VOC detector. Each chamber was then sprayed inside with 5 mL of 100% acetone and sealed for one hour. After this period, the final VOC concentration was measured to determine the amount removed by the plant. Statistical analysis using a one-way ANOVA indicated that the type of plant species had a significant effect on the reduction of VOC concentrations, $F(5, 54) = 4.59$, $p = 0.0015$. The Pothos plant demonstrated the highest removal efficiency, maintaining the lowest mean VOC concentration of 1.305 ppm and the lowest standard deviation. Consequently, the null hypothesis was rejected, and the experimental hypothesis was supported. These findings suggest that specific indoor plants, particularly the Pothos, can play a significant role in improving indoor air quality and reducing the effects of Sick Building Syndrome in residential and workspace environments.

Honorable Mention

Cordova Layla, Chesapeake Bay Governor's School

Impacts Due to Ghost Crab Pots in Chesapeake Bay Shallow Water Ecosystems

The Chesapeake Bay is a vital ecosystem, as it is important both economically and recreationally. The Bay is home to a multitude of species, but most importantly, *Callinectes sapidus*—also commonly known as the blue crab. Crab fisheries are extremely important, as they bring in tons of money each year, which helps to support people as well as jobs. Ghost fishing is when crab pots become disconnected due to reasons such as storms and continue to "fish" species, as a result causing an increase in mortality for a variety of species, not just crabs—which can disrupt the bay's ecosystem. This study compared the length of time that crab pots were left unattended in the water with the number of organisms trapped and the mortality rate over a three-month period to measure the amount of harm that took place the longer the crab pots remained submerged in the water. Results showed that over time the number of crabs caught and mortality both increased. The longer the crab pots remain submerged, the higher the likelihood of crab mortality. Even though past studies highlight how select crabs have been able to move freely in and out of the pots, this does not account for all

crabs. Therefore, the small positives of ghost pots, such as temporary habitation, do not outweigh the negative impacts of ghost pots. Ensuring that the Bay remains healthy is important; therefore, for future research and development, studies show how choosing to use prevention measures and/or more eco-friendly adaptations to pots, such as biodegradable panels, escape vents, or programs to remove these traps, could assist in reducing bycatch numbers in the case of these pots becoming derelict. By using these initiatives, there is a better chance of lowering mortality rates and ensuring that the Chesapeake Bay and crab fishery can thrive for years to come.

Michael Naod, Mills E. Godwin High School

The Effect of Microplastic Concentration on the Hatching Success of Brine Shrimp

The purpose of the experiment was to observe the effects of microplastics on the hatching success of brine shrimp. It was hypothesized that if a higher concentration of microplastic is used, then the hatching success rate of the brine shrimp will increase. Microplastics are a serious problem towards the marine ecosystem because of their ability to negatively affect the hatching rate of brine shrimp. Ten brine shrimp were exposed to either 20 mg, 40 mg, or 60 mg of microplastics. After waiting for 48 hours, the amount of hatched brine shrimp, of the ten, were counted. The control was 0 mg of microplastics. The results showed that 0 mg, on average, had the highest rate of hatched brine shrimp. A t-test was done on the data and all the comparisons, 0 mg vs 20 mg, 0 mg vs 40 mg, 0 mg vs 60 mg, 20 mg vs 40 mg, 20 mg vs 60 mg, 40 mg vs 60 mg, were all significant. The results rejected the null hypothesis and supported the research hypothesis. The results are due to the fact that microplastics reduce the hatching rate of brine shrimp. This is because the presence of microplastics in the habitats of brine shrimp pose a danger to their hatching.

Keelson Samuel, Chesapeake Bay Governor's School

The Effect of Increasing Salinity on the Growth and Germination Rate of Swamp Milkweed (Asclepias Incarnata)

The rapid expansion of data centers in Virginia has prompted innumerable concerns about the sustainability and ecological effects they could potentially have. Data centers draw enormous amounts of water from local rivers in order to function optimally. This "removal of water" results in several potential consequences to the environments they affect and the surrounding wildlife. Estuaries are some of the most unpredictable and dynamic environments in the world. When taking large amounts of water from them this has a negative impact on many things but especially salinity. When huge sums of freshwater are drawn out of a tidal river the saltier water, which is downstream, proceeds to move upstream. The removal of water creates a vacuum that then proceeds to get filled with saltier water. It is very similar to a drought in which freshwater slowly gets replaced with saltier water until the rain returns. The only difference is that the water may never return. This pushes up the salinity gradient further upriver and affects the nature and surrounding wildlife. This study looked to investigate the effects of increased salinity on germination and growth of the Swamp Milkweed. The seeds were germinated and continuously given water at a certain salinity. The treatment groups were 0 ppt, 2 ppt, 4 ppt, and finally 6 ppt. The plant heights were watered and measured every two days over a time frame of three weeks.

A Mixed Design ANOVA test yielded statistically significant results and a p-value of .047. Findings revealed that seed germination rates plummeted at higher salinities, and that even after germination, the continued exposure to salt stunted the growth of the higher salinity plants. These results demonstrate that even moderate salinity increases can negatively affect wetland plant performance, further highlighting the need for more sustainable water management strategies in data center operations and human operations worldwide.

Tyrrell Shane, Chesapeake Bay Governor's School
The Effect of Interspecific Competition Between Green Algae (Chlorella vulgaris) and Cyanobacteria (C. anabaena) Under Eutrophic Conditions

Cyanobacteria anabaena is a bacterial phytoplankton in the Chesapeake Bay that exhibits competitive advantages over green algae phytoplankton such as *Chlorella vulgaris*. This study aimed to detect and quantify a competitive and potential allelopathic advantage of Cyanobacteria over Chlorella in both normal and eutrophic growth conditions. Five jars, or cultures, grew both in monocultures and in mixed conditions through two phases of growth. This included five mono-cultured Cyanobacteria jars, five mono-cultured Chlorella jars, and five mixed cultures of both phytoplankton with, firstly, a plain algae medium and, secondly, a high density of liquid fertilizer. Resulting growth differences suggest that while Chlorella shows signs of stunted growth and replication under competitive conditions, Cyanobacteria is able to further grow with no issues. This trend is consistent with the presence of fertilizer and suggests an inherent competitive advantage of Cyanobacteria over Chlorella. While inconclusive, this may suggest an allelopathic advantage as well, almost completely ceasing Chlorella growth in its presence. As a result of their overlapping but distinct niches, a potential Cyanobacteria replacement of microalgae in eutrophication-prone waters like the Chesapeake Bay may disrupt food chains downstream in pelagic zones. This would be especially true for food chains that rely on the suspension or filter feeding on much larger algae like Chlorella.

Ford Ryan, Chesapeake Bay Governor's School
The Effect of Boating Frequency on the Abundance of Aquatic Wildlife in Shallow Waters

The rise of recreational boating has caused human activity levels in waterways to increase. Resulting from this rise, heightened amounts of pollution are released into the water. Three types of pollution can come from aquatic vessels: physical pollution, noise pollution, and environmental pollution. This study searched for the effects of boating frequency on abundance of aquatic populations in shoreline communities. The study was conducted at a high activity site and a low activity site. The low activity site was selected for its natural shoreline consisting of a riparian forest and various aquatic vegetation, as well as it being a location with low levels of boating activity. The high activity site was on a sandy beach directly outside a marina with a public boating ramp; this site also has a riprap wall. A 25ft seine net, two minnow traps, and two leaf litter bags were used to estimate roughly the entire population at each site. The results of the study revealed statistically significant differences between the high and low activity sampling sites. The low activity location had up to six times more aquatic fauna than

the high activity site. The results of my study as well as other studies raise concerns for aquatic wildlife in high activity areas. If some of these areas are not protected, populations will be decimated.

Rayappa Tejusswin, Mills E. Godwin High School
The effect of Bio-degradable Fertilizer Gels on Runoff

The purpose of this experiment was to find the effects of different forms of fertilizer on the nitrate content in run-off. 25 radish seeds were treated with no fertilizer, 25 radish seeds with biodegradable fertilizer gels, and 25 radish seeds with granular fertilizer. Over a period of five days, the seeds were watered with the same amount of water, and the runoff was collected. Using nitrate test strips, the amount of nitrate in the run-off water was measured and recorded. The control used in the experiment was no fertilizer. It was hypothesized that the run-off with the least amount of nitrate would be the run-off from the bio-degradable fertilizer gel. The mean was determined for each of the levels of the independent variable as shown below. The comparison of no fertilizer (control) (100.00 ppm) to the fertilizer granules (380.00 ppm) to the biodegradable fertilizer gels (124.00 ppm) implies that no fertilizer (control) had the smallest nitrate trace in run-off water on average. A t-test was done on the data, and it was revealed that the data for the no fertilizer (control) vs. biodegradable fertilizer gels was not significant, but the fertilizer granules vs. biodegradable fertilizer gels and no fertilizer vs. fertilizer granules was significant. Overall, the data was significant, meaning the null hypothesis was rejected. This research could lead to further studies that investigate how biodegradable fertilizer gel can be better produced and applied to reduce the negative effects of run-off on ecosystems. This allows for an increased crop yield.

Boak Grace, Collegiate
Accessing Negative Impact of Microplastics on Root Fractals and Shoot Length of Mentha spicata

Microplastics are known amplifiers of drought and hormone disruptors in plants, which in turn affects the plant's nutritional value. When an herbivorous animal is ingesting the plant, it is not only consuming plastic but also consuming less nutrient dense food. With the increase of microplastic pollution, largely due to over creation of plastic products, this food web problem increases. In this study 4 different groups are tested on *Mentha spicata*, or spearmint: tap water (the control), a synthetic auxin group (growth hormone), a microplastic group (with submerged polystyrene), and a microplastic and synthetic auxin group. Since microplastics can create drought in plants and are capable of reducing auxin levels the impact of microplastics on *Mentha spicata* is found by measuring the root complexity (fractal dimension) of mint cuttings propagated in water over the number of days grown. These fractal dimensions were constructed using online software that utilized the box counting method. Additionally, the change in shoot length over the number of days was also calculated. The microplastic groups had significantly lower root complexity than those without polystyrene. However, there was one group out of four that was statistically more significant than the others. Additionally, it was found that the two groups with polystyrene did not have a higher or lower average shoot length compared to the non-polystyrene groups. Yet, out of all four shoot length treatments, the polystyrene and

auxin group had significantly higher shoot growth. To calculate the fractal dimensions, the software counted a 0.50-centimeter box no matter how much root was covering it, so even if the roots were more complex in a water sample versus a polystyrene sample, the software would count the box similarly, which might explain why there isn't one group with a significantly lower root complexity than the others. *Mentha spicata* is considered an invasive species meaning it can survive better than other plants in more hostile environments, which may include exposure to polystyrene.
Singh Vedant, Mills E. Godwin High School

The Effect of Fertilizer Element on Amount of Dissolved Oxygen

There has been a growing increase in harmful algal blooms (HABs) in the world, and they have caused many problems in freshwater lakes. The main cause of these HABs, along with global warming, is chemical pollution through fertilizer. They create dead zones where nothing can survive, leading to contaminated water, wildlife death, and many other things. The objective of this study was to find which chemicals in fertilizer cause the least pollution. The hypothesis was that if three different elements were tested to find the highest dissolved oxygen, potassium would have the highest. Potassium seemed to be the least toxic of the three main elements (Nitrogen, Phosphorus, Potassium), meaning it probably had the highest dissolved oxygen. The control was no fertilizer, as to compare regular lake water to the fertilizer. Forty tanks were filled with 3 liters of lake water, separated into four groups, and given 20 milligrams of a fertilizer or no fertilizer at all. The water's dissolved oxygen was then measured and recorded in a data table for seven days and was repeated until a hundred tanks were measured. It was found that all levels were significant against the control, and potassium had the highest dissolved oxygen after seven days. This is because nitrogen and phosphorus are both minimal in nature, only being found in the air. Potassium is found much more commonly, so the growth rate of the algae isn't affected by the fertilizer as much. Because of this, the dissolved oxygen was able to stay intact.

Environmental & Earth Science D (HS ENV-D)

First Place
Webb Gabriella, Mills E. Godwin High School
Exploring the Effect of Changes in pH on Pyrocystis Fusiformis

The purpose of this study was to investigate the effect of changes in pH on the bioluminescent behavior of *Pyrocystis fusiformis*. As climate change accelerates ocean acidification, understanding how altered pH conditions affect marine microorganisms is increasingly important, particularly for dinoflagellates that play a key role in marine ecosystems and harmful algal blooms (HABs). The hypothesis proposed that slight changes in pH (±0.5 from the control) would increase bioluminescent activity due to stimulated luciferase activity, while larger changes (±1.0) would decrease activity as a result of physiological stress or photoinhibition. To test this hypothesis, cultures of *P. fusiformis* were exposed to five pH conditions: 8.0 (control), 7.5, 7.0, 8.2, and 8.5. A control was used to represent typical seawater conditions and to allow for direct comparison between altered and unaltered pH environments. Bioluminescent flash frequencies were recorded following pH manipulation. The results showed that pH

significantly affected bioluminescent behavior. The greatest mean number of flashes occurred at pH 7.0, while pH 9.0 produced fewer flashes than moderate pH changes. Descriptive statistics demonstrated increased variability at extreme pH levels, and inferential analysis using t-tests confirmed that all pH treatments differed significantly from the control ($p < 0.001$). These results occurred because moderate pH stress temporarily enhanced luciferase activity, while more extreme pH conditions disrupted cellular processes. Overall, this study demonstrates that pH changes significantly influence dinoflagellate bioluminescence and highlights the potential ecological impacts of ocean acidification on marine systems.

Virginia Museum of Natural History Award
Second Place

Saison Georges, Chesapeake Bay Governor's School

How might Forest Clear-Cutting and Tree Buffer Width affect the Variability of Vernal Pools?

Vernal pools are seasonal forested wetlands that rely primarily on direct precipitation and intact canopy structure to maintain stable hydroperiods. This study evaluated how forest clear-cutting and tree buffer width influenced vernal pool volume and variability at the Rappahannock River Valley National Wildlife Refuge in Warsaw, Virginia, from 2019 to 2025. Pools were categorized into four buffer-width groups: Narrow (0 - 17 m), Moderate (18 -30 m), Wide (31 - 60 m), and Control (60 m+). Annual pool volumes were calculated using standardized depth, length, and width measurements, and expressed as a percent change in volume. Precipitation data from NOAA were analyzed to assess winter rainfall variability and classify drought conditions using U.S. Drought Monitor percentile thresholds. These findings indicate that reduced canopy buffering amplified evaporative stress and shortened hydroperiods in pools adjacent to clear-cut areas, while wider buffers maintained hydrological stability. Although precipitation variability remains an important contextual factor, the spatial specificity and timing of volume declines point to forest disturbance as the primary driver. These results underscore the importance of maintaining adequate tree buffer widths to preserve vernal pool hydroperiod stability and ecological resilience under both forest management practices and changing climatic conditions.

Third Place

Burford Layla, Central Virginia Governor's School for Science and Technology

The Ultraviolence of Ultraviolet Light: The Physiologically Compromising Effects of UV-B on Arabidopsis thaliana

The purpose of this study was to highlight overlooked impacts of human energy production by examining the relationship between ultraviolet-B light and hypocotyl length in *Arabidopsis thaliana*. To test UV-B's effect, approximately 135 plants were divided into three groups that received varying exposure times under a UV-B light bulb; plants received either 0 hours, 1.5 hours, or 3 hours of UV-B light daily. All plants received 16 hours of normal light under fluorescent light bulbs daily. All *A. thaliana* plants were grown in an agar medium in petri dishes, using a 1% sucrose solution. Sterility was maintained during agar production, agar pouring, and seed deposition using an autoclave, a biological hood, disposable gloves, micropipettes, bleach,

deionized water, and a 70% ethanol solution. After two weeks of growth, the hypocotyl length of each plant was measured using ImageJ analysis technology. A one-way ANOVA test that indicated significance in the data (p-value <.01, alpha value .05) led to the conduction of a post-hoc Tukey test that indicated a significant difference between all three groups (p-value <.01 for all groups). Plants exposed to 0 hours of UV-B had significantly longer hypocotyls than plants in both the 1.5-hour and 3-hour exposure groups (means of 4.65 mm, 3.98 mm, and 3.11 mm, respectively). Experimental data supported the research hypothesis, which predicted that *A. thaliana* hypocotyls would be longest when exposed to no UV-B. Overall, the experiment supported the existence of a negative relationship between hypocotyl length and UV-B exposure.

Honorable Mention

Fitzgerald, Genevieve, Central Virginia Governor's School for Science and Technology
Oil Absorbance Rates of Natural and Synthetic Absorbants

The purpose of this experimental study was to determine if natural absorbents were more effective in cleaning up oil spills than synthetic absorbents. Two natural absorbents (coconut coir and sawdust) were tested against one synthetic absorbent (Huron NEOSafe) to determine which resulted in higher absorbance rates of oil. All three absorbents were placed in an oil and water mixture and left to sit for 24 hours before being taken out and left to dry for 48 hours. On average, both of the natural fibers absorbed more oil and water than the synthetic. A single factor ANOVA test was run to determine statistical significance and returned a p-value of .01, which is smaller than the established alpha value of .05. A post-hoc Tukey test then determined which groups had statistical significance between them. The research hypothesis–which stated that if both natural and synthetic absorbents were used to clean an oil spill, the natural absorbents would absorb more–was partially supported based on the results of the post-hoc test and the difference between the coconut coir and Huron NEOSafe groups returning a p-value of .01, while the difference between the sawdust and Huron NEOSafe groups returned a p-value of .14. In conclusion, the natural absorbents are partially more effective than synthetic absorbents.

Nayak Aarav, Mills E. Godwin High School
Analyzing Different Water Sources on Microplastic Count

The study investigated the concentration of microplastics in four distinct water sources: tap water, bottled water, lake water, and river water, addressing a critical environmental and health issue. Microplastics, tiny plastic particles originating from larger plastics, entered water systems through various pathways such as wastewater effluent and the degradation of larger debris. The research emphasized the need to understand microplastic concentrations to assess potential risks to both ecosystems and human health. The independent variable in this experiment was the water source, while the dependent variable was the number of microplastics per milliliter of water. A total of 63 mL of hydrogen peroxide was added to each water source to facilitate the analysis. Samples were examined under a microscope, and the recorded data were analyzed statistically. Results indicated that tap and bottled water had similar, low concentrations of microplastics, while the lake and river water exhibited much greater

variability and higher mean microplastic counts. The hypothesis that Echo Lake water would have significantly higher microplastic concentrations than bottled water was supported by the findings. The statistical analysis, specifically a two-sample t-test, revealed significant differences between the microplastic concentrations across water types, leading to the rejection of the null hypothesis. Overall, the study highlighted concerning trends regarding microplastic pollution in freshwater systems, underscoring the need for further research and potential regulatory measures.

Kuk Wren, Central Virginia Governor's School for Science and Technology
The Effects of L-Ascorbic Acid on the Heat Tolerance of Hydra viridissima

Coral is essential to ecosystems globally; nevertheless, they are facing devastating bleaching events due to ocean warming. To potentially combat the harmful effects of heat stress, the antioxidant L-ascorbic acid was investigated as a pre-treatment to a close relative, the species *Hydra viridissima,* under a simulated "heat wave". Health-related data on the Hydra was collected on four different scales: survivorship, morphological stress, color, and reproduction. All testing was conducted through Two-Way ANOVA's, which revealed - specifically through the morphological stress test - that the pre-treatment may have had a significant effect on the heat tolerance of the Hydra as the p-value was .04 (α = .05). The data did not support my research hypothesis, but in essence, the results suggested that heat stress impairs the health of *Hydra viridissima* and the properties of the antioxidant L-ascorbic acid require further investigation.

Henry W. MacKenzie Jr Environmental Scholarship
Holland Lucas, Blacksburg High School
Modeling Spatial Temperature Structure Using Generalized Additive Models and Local Indicators of Spatial Association

Neighborhood-scale temperature in Virginia is spatially clustered and is not well-described by strictly linear relationships. Census block-group mean temperature estimates from Virginia Heat Watch were analyzed using Local Indicators of Spatial Association (LISA) and generalized additive models (GAMs) to characterize clustering and to estimate nonlinear associations with built-environment and socioeconomic predictors. Spatial dependence in temperature was quantified using global Moran's I, and local hot-spot/cold-spot patterns were mapped using LISA with contiguity-based spatial weights. Temperature was then modeled with GAMs including smooth terms for percent tree canopy, percent impervious surface, median household income, and percent water cover, with county fixed effects included. A two-dimensional smooth over longitude and latitude was added to capture broad geographic structure not represented by the measured covariates. Residual spatial autocorrelation was evaluated using Moran's I. Temperature showed strong positive spatial autocorrelation and clear local clustering. Across models, impervious surface and tree canopy were the most consistent predictors of higher temperature, and their effects were nonlinear with evidence of threshold behavior. Median household income showed weaker and less stable associations once land cover and spatial structure were included, consistent with socioeconomic patterning operating partly through land-cover configuration. Adding the longitude–latitude smooth increased explained deviance and reduced, though did not

eliminate, residual spatial autocorrelation. Results support targeting mitigation where clusters of elevated temperature coincide with high impervious cover and low canopy, rather than relying on broad averages.

Hartke, Indira, Hampton Roads Academy
Green Algae and Its Role in Promoting Ecological Balance

Green algae are one of many autotrophic eukaryotes that can both photosynthesize and consume microorganisms in their habitats (Krajick, 2021). It is hypothesized that early photosynthetic prokaryotes, known as cyanobacteria, were engulfed by a host cell, resulting in the host cell becoming both photosynthetic and heterotrophic (Oborník, 2019). The growing presence of pollutants and excess waste in the environments where these algae thrive is increasingly disrupting the balance of aquatic ecosystems. This experiment aims to observe how the growth of *E. coli*, a common pollutant, is affected in the presence of green algae. *E. coli* samples were added to culture tubes containing one of three species of green algae (*Chlamydomonas*, *Scenedesmus*, and *Spirogyra*) and their growth mediums. Bacterial growth was assessed by performing a seven-step tenfold serial dilution after incubation for 24 and 48 hours in a shaker incubator at 32°C. Single colonies were counted, and the bacterial concentration was calculated. It was hypothesized that the presence of each green algae species would reduce the bacterial population. The results show that although the number of bacteria decreased slightly after the addition of green algae, the decrease was not as pronounced as predicted. Furthermore, the *E. coli* exhibited a phenotypic change relative to its original strain upon exposure to the algae. This means that in their natural environments, the bacteria may mutate to survive the presence of the algae. The decrease in *E. coli* growth indicates that green algae can still feed on bacterial pollutants in the water. However, the presence of nutrients in the growth medium does not favor bacterial consumption by the algae; therefore, it may not be a viable alternative for treating water contamination in their natural environment.

Abdelbagi Amna and Amundson Clara, Yorktown High School
Assessing Soil Microbial Response to Various Fertilizer Treatments

The fertilizers used for farmland near the bay are largely synthetic, prioritizing chemicals to promote rapid plant growth. However, these chemicals kill key microbes in the soil, diminishing soil into dirt. This is presently a massive issue around the world, with fertile farmland being turned into dustbowls. This science project seeks to find an organic alternative to synthetic fertilizer, with the goal of promoting soil health over rapid production in an effort to preserve our farmlands. Soil microbial biomass is an important indicator of soil health, as microorganisms are essential for fertile land and nutrients. While synthetic fertilizers prioritize rapid plant growth, their chemical composition negatively impacts the plants in the ecosystem. It was hypothesized that if plants with soil exposed to organic manure, it would yield a higher microbial organism amount than soil treated with synthetic urea because synthetic fertilizers have a high amount of nitrogen, and often does not preserve the soil microorganisms. The independent variable was the type of fertilizer treatment (untreated, manure, urea), and the dependent variable was the microbial colony count per plate. To stimulate a similar environment as a farm, wheatgrass was grown in 24 points divided into three groups of

eight, each labeled as their independent variable. After a growth period of three and a half weeks under grow lights, soil samples were collected from each trial. Microbes were extracted using a serial dilution method, where 1 gram of soil was mixed with 10mL of sterilized water. 0.1mL of the solution was then inoculated onto agar petri dishes using a glass spreader and a micropipette. The plates were incubated for two days to allow for bacterial colonies to form. The data was analyzed by counting the individual colonies for each trial and using an ANOVA test to determine the statistical significance of the results, and a p-value of 0.06 was determined. Out of all three experimental groups, the results revealed that the synthetic fertilizer independent variable group was the most successful at preserving the greatest number of microbial colonies as the mean was 169 cells, while the untreated independent variable group, the control, was the least successful as the mean was 109 cells.

Rajagopal Sagunthala, Mills E. Godwin High School
The Effect of CO2 Reducing Paint on the Reduction of CO2

The purpose of this experiment was to find the effects of CO2 reducing paints on the reduction of CO2. CO2-reduction paints have been used recently in the construction industry to reduce CO2, and these paints may have similar effects on CO2 reduction. Boxes representing walls of a house were painted with lime-based paint, bio-based paint, and algae-based paint. The boxes were left for CO2 reduction for a day, and then their carbon dioxide levels were measured. The control that was used in this experiment was normal latex paint. A research hypothesis was formulated that the algae-based paint will result in a higher CO2 reduction. The results revealed that the boxes painted with algae-based paint reduced to 68.1 ppm more than lime-based paint, 117.6 ppm more than bio-based paint, and 215.2 ppm more than normal latex paint. A t-test was done on the data, and it revealed that the data was not significant for lime-based paint vs. bio-based paint but was significant for the other t-tests. The results did support the research hypothesis. It is believed that the results are due to the fact that algae has been used in photosynthesis to reduce CO2 and absorb CO2 in its process to grow, so it functions the same way in the paint to reduce CO2. This research could lead to further studies that investigate the saturation point of algae-based paint for how long it can keep reducing CO2 and how the amount of spirulina powder will affect the effectiveness of CO2 reduction.

Ho Elina, Mills E. Godwin High School
The Effect of pH on Lemna minor Methylene Blue Absorption

Synthetic dyes such as methylene blue are pollutants that degrade water quality and disrupt ecosystems, creating a need for sustainable wastewater treatment. Phytoremediation using duckweed (*Lemna minor*) offers a low cost and environmentally friendly method for dye removal. This study investigated the effect of solution pH on methylene blue absorption by *Lemna minor* to determine which pH has the highest removal. It was hypothesized that if the pH is 6, then it would produce the greatest absorption due to favorable conditions. Solutions of approximately 30 mg/L methylene blue were prepared at pH 5, 6, 7, and 8, with pH 7 serving as the control as it represents typical freshwater. Twenty-five trials per treatment were used, and dye concentration was measured with a spectrophotometer at 665 nm over 72 hours. T-tests at $\alpha = 0.01$

revealed significant differences between the control and both the pH 5 and 6 treatments, but no significant difference was observed for pH 8. The pH 5 treatment showed the lowest final dye concentration, indicating the greatest absorption. Enhanced absorption under acidic conditions may result from increased dye solubility and improved plant uptake, while alkaline conditions may limit absorption. These results indicate that solution pH affects methylene blue uptake and suggest that mildly acidic conditions optimize *Lemna minor* phytoremediation. Future studies could explore narrower pH ranges, longer exposure times, and additional dye types to improve wastewater treatment efficiency.

Mathematics, Theory & Modeling (HS MTM)

Mathematics Award

First Place

Li Adelaide, Blacksburg High School

Long-Term Sustainability of a Wealth Tax Base Under Liquidity Constraints: An Agent-Based Modeling Approach

Existing research finds that wealth taxes can reduce inequality with limited short-run behavioral distortions, but the long-run sustainability of the wealth tax base remains underexplored. Empirical studies largely focus on short-term responses, while theoretical work emphasizes administrative concerns, leaving unclear whether taxed individuals can continue paying the tax without depleting their wealth. This study addresses this gap using an agent-based model to examine long-term wealth retention under a flat tax on net worth. Agents are parameterized using data from the U.S. Survey of Consumer Finances to reflect realistic distributions of wealth, liquidity, and debt. Each period, agents invest and pay taxes using liquid assets, liquidating wealth only when necessary. To isolate tax base sustainability, the model excludes income growth, labor earnings, market shocks, and other taxes. Simulation results suggest that wealth tax rates up to approximately 15 percent can sustain a stable taxable population without widespread wealth collapse or excessive asset liquidation.

Second Place

Madaan Arjun, Mills E. Godwin High School

The Relationship Between the Nature of the Primality of Natural Numbers on Collatz Stopping Times

The Collatz Conjecture (a.k.a. "$3n + 1$ problem") is one of the oldest, unsolved problems in mathematics. The recursive definition of the function is as follows.

$f(n) = f(\frac{3n+1}{2})$ if $n$is odd, $f(\frac{n}{2})$if $n$is even

This function is for anywhere n is a natural number (a positive integer greater than 0). Looking carefully at these rules, an infinite "loop" seems to form between $1$and 2, as $f(1) = f(\frac{4}{2}) = f(2) = f(\frac{2}{2}) = f(1)$and so on. The Collatz Conjecture states that all natural numbers will eventually reach the aforementioned loop if the function is continuously

applied. Solving this problem would probably lead to advances in number theory, cryptography, and dynamic systems. This experiment takes different types of prime numbers (Pythagorean and Non-Pythagorean) and compares their Collatz Stopping Times. The primes in this experiment (denoted by p) were always $3 \leq p < 2^{20} + 1$. The research hypothesis was that Pythagorean primes would have a lower stopping time due to modular arithmetic. The "Python" programming language was used to collect data and generate graphs. Pythagorean primes were shown to reach 1 almost 12 steps faster. A Mann-Whitney U Test determined a p-value that was $< 10^{-183}$.

Third Place

Balasubramanian Rishvanth, Deep Run High School

Bounding the Number of Critical Points for a Potential Function with 3 charges

Conjecture 3 of Boris Shapiro's paper on polynomials proposes a fundamental problem: Does the function $\psi(x) = \sum_{i=1}^{N} \frac{q_i}{((x - x_i)^2 + y_i^2)^{\alpha}}$ contain N real maxima or less. Yet, relatively little progress has been observed for this conjecture, with the case of $N = 3$ and $\alpha = 1$ case not proven. In this project, I proved conjecture 3 under specific conditions when $N = 3$ and $\alpha = 1$. Given that there are three equally charged points which are equidistant from each other on the x-axis with one centered at the origin, conjecture 3 holds. Under the same relative location of points, conjecture 3 also holds if the charges satisfy the following conditions: $q_1 > 0, q_2 = q_3, \text{and } q_2 > \frac{q_1}{2}$ or alternatively, $q_1 < 0, q_2 = q_3, \text{and } q_2 < \frac{q_1}{2}$. It is presumed that the point represented by q_1 is centered at the origin and the remaining points are to the left and right of the origin. In addition to the mathematical investigations, numerical simulations were conducted to generate graphs of the potential for randomly generated points and charges. These numerical simulations were written using NumPy and Matplotlib and restricted all points to the x-axis but did not condition them to be equidistant from each other. For all of the three trials conducted, conjecture 3 remained valid. On a broader note, one unique aspect of conjecture 3 is $\psi(x)$'s similarity to the electrostatic potential in Maxwell's conjecture, a famed problem in electrostatics. New insights into conjecture 3 could open up new pathways to prove Maxwell's conjecture.

Virginia Sea Grant College Program Award
Honorable Mention

Butler Philip, Osbourn Park High School

The Game of Overfishing in Chesapeake Bay

Introduction: *Brevoortia tyrannus (*Atlantic Menhaden), a small oily fish located across the East Coast, is experiencing a population decline specifically in Chesapeake Bay due to potential overfishing. This project was intended to formulate a solution to the decreasing Atlantic Menhaden population by utilizing Game Theory while providing insight into how Game Theory can be used in environmental conservation.

Methodology: Background research was conducted to determine the yearly income from the harvest of Menhaden in Chesapeake Bay by Omega Protein and Individual

Fisheries. These fisheries represented players and were provided with a hypothetical scenario to either increase, remain constant, or decrease harvest over three time periods without cooperation. Matrices were developed by adjusting income from the foundational cell to reflect stock depletion of Atlantic Menhaden. Key Game Theory concepts of Nash Equilibria were applied to the matrices for analysis. A real-life game using physical playing cards was designed to display the applicable nature of Game Theory.
Results: Game Theory provided a mathematical solution which can aid the recovery of Atlantic Menhaden. Without cooperation, players are incentivized to disregard the species' well-being for commercial gain in all time periods, ultimately leading to an endangered Menhaden population and a damaged Chesapeake Bay ecosystem. In contrast, with collaboration between Omega Protein and Individual Fisheries, players are incentivized to lower harvest quantity, allowing Atlantic Menhaden to recover while creating a sustainable harvest for fisheries.
Conclusion: This application of Game Theory demonstrated that sustainable cooperation between fisheries is necessary to preserve the species and improve the ecological state of Chesapeake Bay, while also exhibiting that its applicable nature can provide solutions to other conservation efforts.

Honorable Mention
Johnson Natalie, Chesapeake Bay Governor's School
DubStep: An Algorithm for Dubins' Path Planning

In a world dominated by technology, air safety and regulation is critical to the function of the industry. Globally, the aviation industry supports over $4 trillion in economic activity and contributes 3.9% to global GDP. There are 100,000 flights globally, and almost 45,000 flights that take off in the United States alone every day, including commercial, cargo, and private aviation. One way to ensure air safety and implement mathematical modelling is path planning. The goals of this project are to create a simple algorithm, associate math with each of the steps in the algorithm and translate it to Python code. Using both the arc length and tangent length, calculate the length of the entire path for each turning direction. This is done by adding both of the lengths. Once both paths have been calculated, the optimal path can be chosen. In general, this is the shorter path. Using Microsoft Visual Studio Code, the algorithm was translated to Python. The code was written using the math associated with each step of the algorithm. The algorithm allows a simple Dubins' Path's parameters, such as start and end positions, headings, and turn radii, to be inserted to calculate a mathematically optimal route to the end point. A strength the algorithm possesses is that it takes into account special cases that may occur and is universally applicable for basic path computation. By improving the algorithm beyond its current simplicity, the program would become a highly functional and practical tool for airspace.

Honorable Mention
Owen David, Central Virginia Governor's School for Science and Technology
A Comparative Analysis of ChatGPT, Gemini, and Meta AI in Mathematical Problem Solving: Accuracy and Response Efficiency

The purpose of this study was to determine if the difficulty of mathematical questions had a significant impact on the accuracy and response time of certain AI models. This experiment was conducted at a local high school during the month of November 2025. Each of the three AI models were asked 90 different mathematical questions, 30 of them being easy, 30 of them being of medium difficulty, and 30 of them being of a hard difficulty. All of the response times were recorded, and an ANOVA test was conducted to determine significance. The alpha value was set to .05, and the p-value was determined to be .07. These results presented a trend toward significance, but did not fully support the research hypothesis, which stated if the complexity of math problems increases, then AI systems will exhibit reduced accuracy and longer response times, with varying results across models. To summarize, the difficulty of the questions did not have a significant impact on the overall performance of the tested AI models.
Shetty Saharsh, Mills E. Godwin High School

The Effect of Receptors on their binding energy with BiTE

Neuroblastoma happens when tumors in the nervous system grow uncontrollably. However, it can be treated with BiTE therapy which uses receptors that bind to BiTE to destroy cancer cells. This therapy has many implications, like improving knowledge of cancer treatments. The purpose of this experiment was to determine which receptor produced the strongest binding energy with the antibodies used. The researcher hypothesized that if CD16a is used, then it would produce the highest binding energy. No control was used because the model cannot work without a receptor. Amino acid sequences were obtained using UniProt and AlphaFold 3 which were used to design the receptors. A shell script was made, and calculations were performed for each receptor-antibody interaction using HDOCK and PRODIGY. These binding energy values were analyzed, and the Glypican receptor showed the strongest interaction with BiTE. The Glypican receptor had the highest average binding energy at −14.6 kcal/mol which may be due to the strong attraction between heparan sulfate chains. However, the CD3 receptor had the lowest at −12.7 kcal/mol, indicating the least precise data. Moreover, even though the Glypican-2 produced the highest standard deviation which is 2.949 and CD3 produced the lowest, the t-tests were insignificant, and the results were due to chance. There were sources of error, like Python code that may have caused skewed results and lower number of antibodies. Future studies should include multiple receptors to create a more effective BiTE molecule and increase the number of antibodies.

Medicine & Health A (HS MDH-A)

AJAS Alternate
First Place
Li Jerry, Mills E. Godwin High School
Curcumin suppresses HNSCC tumorigenesis through directly targeting FOSL1/JUN

Natural products and affordable herbal medications have emerged as promising alternatives for cancer therapy, particularly for patients with limited access to standard treatments. Among these, curcumin, the bioactive polyphenol from *Curcuma longa* (turmeric), has shown broad anti-cancer potential. However, its molecular mechanism

remains poorly defined, especially for head and neck squamous cell carcinoma (HNSCC). Here, we identify curcumin as a potent inhibitor of HNSCC tumorigenesis and explore its underlying mechanism. Comparative analyses of three anti-cancer natural products, including curcumin, gingerol, and allicin, revealed that only curcumin robustly inhibited HNSCC cell proliferation, invasion, and cancer stem cell self-renewal, with potency comparable to or superior to cisplatin. Transcriptomic and Gene Set Enrichment Analyses demonstrated that curcumin significantly suppressed FOSL1/AP-1 signaling, a well-known key oncogenic signaling that promotes malignant progression of HNSCC. Biophysical and biochemical assays showed that curcumin directly binds to the FOSL1/JUN heterodimer (Kd ≈ 10 μM), disrupting its DNA-binding activity. In agree with this finding, chromatin immunoprecipitation confirmed that curcumin inhibited FOSL1/JUN recruitment to the promoter of cancer stem cell marker gene *BMI1*, as well as super-enhancer–associated oncogenic loci such as *MET*, *EGFR* and *TP63*. At last, curcumin treatment profoundly suppressed HNSCC tumor growth in xenograft model and exhibited superior efficacy compared with the FOSL1/AP-1 inhibitor T-5224, without apparent toxicity. Collectively, our findings identify FOSL1/JUN complex as a direct molecular target of curcumin and uncover a novel mechanism by which this accessible natural product suppresses HNSCC tumorigenesis, supporting its potential as an affordable and safe therapeutic option for cancer treatment.

Second Place

Zunaira Khan, Mills E. Godwin High School

Lectin Based Analysis of Pancreatic Islet-Surface Integrity in Chronic Pancreatitis

Instant blood mediated inflammatory reaction (IBMIR) is a major cause of early graft viability loss during total pancreatectomy with islet auto transplantation, even when islets are genetically matched to the recipient. Chronic pancreatitis exposes islets to prolonged inflammation and fibrosis prior to surgery, potentially remodeling the pericellular coat that regulates immune recognition and coagulation. Because this surface layer is the first structure to contact blood during transplantation, disease driven changes may increase susceptibility to IBMIR and compromise outcomes. The purpose of this study was to determine whether chronic pancreatitis alters sialylation of the islet pericellular coat using lectin-based fluorescence analysis. It was hypothesized that islets from chronic pancreatitis tissue would show reduced binding of sialic acid specific lectins compared with non-pancreatitis control tissue, indicating disease associated desialylation. Normal pancreas tissue served as the control to establish baseline lectin binding patterns. Formalin fixed pancreatic sections from control and chronic pancreatitis samples were stained with fluorescent Sambucus nigra agglutinin and imaged under standardized microscopy conditions. Mean fluorescence intensity was quantified across multiple islet regions of interest, and statistical analysis included measures of central tendency, variation, and an independent samples t-test. Chronic pancreatitis tissue exhibited markedly lower mean lectin binding intensity than control tissue. Inferential analysis demonstrated a highly significant difference between groups ($t = 9.544$, $df = 18$, $p < 0.001$), supporting rejection of the null hypothesis. Qualitative imaging revealed weaker and more discontinuous lectin staining in chronic pancreatitis islets. These findings indicate that chronic pancreatitis is associated with significant loss

of islet surface sialylation, suggesting reduced glycoimmune protection that may contribute to increased IBMIR related injury during surgical islet transplantation.

Third Place

Syed Akbar, Central Virginia Governor's School for Science and Technology

The Effect of Gut Microbiota on Autism-Like Behaviors in Drosophila melanogaster

The purpose of this study was to examine how different diets influence "autism-like" grooming behaviors in *Drosophila melanogaster* (fruit flies). Two genotypes were tested (Normal and Fmr1 mutant), and each fly group was divided into three different diet groups. The control group was only fed standard fly food; the Pro + Prebiotic group received standard fly food with roughly 1.8×10^9 colony-forming units (CFU) per vial, and the High Sugar group was fed normal fly food with the addition of roughly .5 grams of sugar per vial. Due to this being a behavioral study, grooming patterns were measured for a total of 120 flies (20 per condition) using a manual grooming assay. The results indicated that the control group, for both genotypes, exhibited the largest number of grooming bouts, whereas the Pro + Prebiotic group and High Sugar groups showed less grooming frequency. By using a 2-way ANOVA with an alpha value of .05, the study determined that diet and genotype both affect grooming behavior (both independent variables had a p-value of <.01). The post-hoc Tukey test also confirmed significant differences between the control and experimental diet groups in both genotypes. This supported the research hypothesis, which predicted that the Pro + Prebiotic diet would have a reduction in grooming behavior. The findings from this research can be used to further explore microbiome-based treatment for symptoms linked to autism spectrum disorder.

Amin Vihani, Mills E. Godwin High School

The Effect of Different Types of Sunscreens on UV Protection

The purpose of this experiment was to determine the effects of different types of sunscreens on UV protection. Sunscreen is needed by anybody, any age, gender, or occupation, and many do not know which sunscreens to buy out of the thousands on the market. The results of this experiment can help these people acquire sunscreen that can keep them safe during work, play, or daily activity. The three types of sunscreens used were mineral, hybrid, and chemical. A mineral, chemical, and hybrid sunscreen were all evenly spread on plastic sheets cut from Ziploc bags in order to imitate the skin and placed into direct sunlight. In 4 intervals of 20 minutes, their UV level was measured and recorded. The control in this experiment was the use of no sunscreen. The results revealed that mineral sunscreen worked the best overall, having the lowest UV value after the full 80 minutes as well as working faster than the chemical and hybrid sunscreens. Six t-tests were conducted which revealed overall significance as well as the rejection of the null (5/6 t-tests showed statistical significance). The results supported the research hypothesis that mineral sunscreen would be most effective. The results are believed to have occurred due to the difference in active ingredients between the sunscreens as well as how they protect the skin. Further research could include testing on different skin types as opposed to the plastic sheets used as test subjects in this experiment or different brands of sunscreen.

Bubulac Stefan, Mills E. Godwin High School

The Effect of Toothpaste pH and Fluoride Content on Short-Term Acid Protection of Eggshell as an Enamel Substitute

Acidic foods and drinks can erode enamel and increase risk of cavities. Toothpaste is widely used to slow erosion, so identifying effective toothpastes may help people make more informed oral care choices. This study investigated how toothpaste treatments affected short–term protection against acetic acid erosion using eggshells as enamel substitutes. The hypothesis was that toothpastes with higher fluoride concentration and near neutral/slightly basic pH would yield the lowest percentage mass loss of eggshells during acid exposure. Seven independent variable levels were tested: Colgate Total SF, Rx5000, Enamelon, Elmex Sensitive Professional, Dr. Sheffield's Mixed Berry, Neem Essential, and a no–treatment control ("None"). Toothpastes had pH values 4.5–8.0 and fluoride concentrations 0–5000 ppm. For each treatment, 25 preweighed chips were immersed for 40 minutes in 3:1 distilled water: toothpaste slurry and for 15 minutes in 5% acetic acid, with rinsing and drying after each step, and then reweighed. The dependent variable was the percentage mass loss of eggshell samples after acid exposure. Higher fluoride toothpastes with near-neutral/slightly basic pH showed the greatest protection, with the lowest mass loss observed for Colgate (7.028%), followed by Rx5000 (8.240%). Enamelon produced the highest mass loss (11.806%), followed by the control (11.310%). T–tests ($\alpha = 0.05$) found 19 of 21 comparisons significantly different in value; Rx5000 vs. Elmex and Enamelon vs. "None" were not. These results support the hypothesis that higher fluoride and near neutral/slightly basic pH provide the greatest protection; however, the fluoride compound also had to be considered to explain all experimental findings.

Culberson Giana, Izumi Coco, Yoo Alyssa, Governor's School @ Innovation Park

When Your Gut Becomes a Brewery: Proving the Efficiency of Preventative Measures for Auto-Brewery

Auto-Brewery Syndrome (ABS) is a rare disorder in which gut microorganisms ferment dietary carbohydrates into ethanol, causing intoxication symptoms without alcohol consumption. Because ABS flare-ups are closely linked to carbohydrate intake and microbial imbalance, this study investigated how different carbohydrate types and probiotic supplementation influence fermentation activity in a gut-like environment. Simple sugars were hypothesized to produce higher levels of fermentation than complex carbohydrates, while probiotics were expected to suppress ethanol-associated fermentation through microbial competition. Four carbohydrate types, glucose, fructose, sucrose, and starch, were tested using yeast cultures with and without probiotic supplementation. Fermentation activity was monitored over a 48-hour period in sealed containers equipped with balloons and carbon dioxide sensors. Carbon dioxide production was used as an indirect measure of ethanol formation, as both are byproducts of yeast fermentation. Results showed that simple sugars produced significantly greater fermentation than complex carbohydrates. Glucose generated approximately 9 times more carbon dioxide than starch over 48 hours, indicating substantially higher ethanol-producing activity. In contrast, starch exhibited minimal fermentation. When probiotics were added to glucose treatments, carbon dioxide production decreased by over 78% compared to glucose-only controls. This reduction

suggests that probiotics effectively inhibit yeast activity by competing for nutrients. These findings support two key dietary strategies for managing ABS, reducing intake of rapidly fermentable simple sugars, and increasing probiotic consumption to limit yeast overgrowth. Overall, this study highlights the potential of preventative, diet-based approaches for ABS management while emphasizing the need for future experiments that more closely simulate human gastrointestinal conditions.

Dhingra Anusha, Mills E. Godwin High School
The Effect of Natural Remedies on Planaria Regeneration

The purpose of this experiment was to find the effect of different natural remedies on planaria regeneration. Currently, planaria are being researched due to the similarities they have with human skin in hopes of figuring out potential cures and treatments for external injuries. The planaria were treated with either 0.13g of calendula extract, yarrow tea, or honey & turmeric paste before being set aside to grow and be observed. The planaria were measured after 10 days. The control used in this experiment were the planarians treated with no remedies. It was hypothesized that the planaria batch treated with honey & turmeric paste would have the most growth over a ten day period of time. The results revealed that the planaria treated with yarrow tea grew, on average, more than those treated with calendula extract and honey & turmeric paste, as well as the control group. A t-test was done on the data, and it showed that the data was significant for all the natural remedy levels vs. the control. The results did not support the research hypothesis but did support that natural remedies helped in the regeneration process of planaria. It is believed that the results are due to the fact that yarrow tea had cyanogenic glycosides and flavonoids to prevent inflammation and chemically protect the wound. This study could lead to further research into altering the concentration of yarrow tea as well as if different forms of yarrow have stronger impacts on planaria regeneration.

Ghimire Sambridha, Osbourn Park High School
Predicting Post-Surgical Infection Risk Using Interpretable Machine Learning

Surgical site infections are a significant concern in the healthcare world, and they cause patients to have to spend many extra days in the hospital, while also increasing financial burden. On top of that, they can lead to serious health problems, such as death. Early detection of SSIs is challenging because symptoms often manifest after disease progression. The project aimed to create a machine learning model that is able to predict the risk of a post-surgical infection with simulated patient data. A synthetic dataset of 350 simulated patients that was generated in order to model clinically relevant variables. This includes their age, temperature, heart rate, blood cell count, wound redness, time since surgery, and days since surgery. Once that was created, the machine learning model was used to analyze these features and patterns. After analyzing tons of patients' data, the model was trained to accurately generate a probability of a post-surgical infection. The model was then trained by using 80% of the simulated data set, then using the remaining 20% to test the model. Once the machine learning model had been finished, in order for the public to have access to it, an interactive website in which users can input their own patient information and then

receive an accurate infection risk percentage was created. In conclusion, this model shows how machine learning can be applied to healthcare problems in a safe way.

Hill Gracie Sirens, Chesapeake Bay Governor's School
Ear Protection and Firefighters Hearing

Emergency response sirens, engines, and firefighting equipment produce noise levels that can be classified as very loud, with siren noise often exceeding 110-120 decibels. Prolonged exposure to sound levels at or above 85 decibels can substantially increase the risk for the development of noise-induced hearing loss. This study used survey results (78 respondents) and hearing tests to compare hearing protection usage and hearing loss of firefighters. Survey results show that only about 50% of firefighters regularly wear hearing protection. The results also show that about 80% of respondents believed they had some signs of hearing loss regardless of if they wore hearing protection or not. While not statistically significant the younger firefighters had a higher usage of hearing protection and lower percent of hearing loss than older age groups. The David and Clark headset was the most used hearing protection and sound meter test found that it significantly reduced siren decibel levels to below hazardous levels if worn properly.

Kumar Devansh, Maggie L. Walker Governor's School
A Novel Type 3c Diabetes Biomarker: Uncovering Islet Amyloid Polypeptide Aggregation in Chronic Pancreatitis

This study investigated the presence of Islet Amyloid Polypeptide signals in chronic pancreatitis patients. Chronic pancreatitis is one of the most pressing issues involving pancreases currently. Often in chronic pancreatitis and type 2 diabetes, the endoplasmic reticulum is put under stress. Such stress can cause protein misfolding while proteins are being secreted in cells. Within islet beta cells, insulin and amylin are produced and secreted together through the endoplasmic reticulum. This study investigated the correlation and presence of amyloid in chronic pancreatitis, that has not been investigated previously. Specifically, this study aimed to determine the presence of amyloid in chronic pancreatitis patients, when compared to a group of type-2 diabetic patients. While the results did not support the initial hypothesis, as chronic pancreatitis samples did not demonstrate similar IAPP staining to the diabetic samples, significant experimental data was collected, providing the basis for further research to deepen knowledge regarding diabetes and chronic pancreatitis.

Orem Keegan, Chesapeake Bay Governor's School
The Effect of Terrain on Cross Country Running Times and Biomechanics

This study was conducted to determine the impact that terrain has on a runner's performance, including time and their biomechanics (stride length, running cadence, and ground contact time). Running plays, a key role in everyday life and is a part of many competitions as well as basic exercise. Terrain is a key variable when determining performance as its factors can affect the biomechanics of a person. The study was conducted by using three distances, 1600, 800, and 400 meters along with three terrains, grass, track, and asphalt to measure time, stride length, running cadence, and ground contact time. This study examined 135 running events with 6 total runners with

a similar range of athleticism and physicality, all of whom had been conditioning before testing commenced. Strava was used to track time and steps which provided the data necessary for comparing the terrains and distances. Results found that track was the best optimal surface as it provided the fastest times, longest stride length, lowest cadence, and shortest ground contact time overall. All data obtained was found to be significant and all null hypotheses were rejected as a result. In conclusion, this data found means that terrain does affect performance and should be taken into account when assessing a person's overall potential and condition. These findings can be used by coaches to train their runners on the best surface that produces the lowest times. It can also assist in injury prevention as fatigue and muscle overuse can be avoided by not straining runners on a surface that drains energy and lessens performance.

Soin Avi, Collegiate
Effects of Different Levels of Processed Foods on Mealworm Growth and Development

This research investigates the impact of food processing on the growth and development of darkling beetle larvae *(Tenebrio molitor)*, commonly known as mealworms. Mealworms served as a model organism to understand how processed foods affect biological systems. Mealworms were divided into three diet groups: organic rolled oats (minimally processed control), organic toasted oats cereal (moderate processing), and organic honey nut toasted oats cereal (highly processed with added sugars). Mealworm growth was measured by tracking the changes in total mass and calculating the total percent change for each group. The results show a significant difference in mealworm growth across the different diets (p = 0.0044). Mealworms that were fed minimally processed organic rolled oats exhibited the highest average mass increase (50.0 ± 4.0 % change in mass over 22 days). The growth in the control group was approximately twice that observed in the other two groups. The moderately-processed organic toasted oats cereal group showed an average mass change of 26.0 ± 5.0%. The highly processed organic honey nut toasted oats resulted in the slowest growth, with an average mass change of 22.0 ± 5.0%, and this group was the only one to exhibit mealworm mortality. This study supports the hypothesis that mealworms fed more processed oats will grow differently from those in the control group. The results have implications for both sustainable insect farming and for informing human diet choices regarding processed grains.

Stevens Mercedes, Chesapeake Bay Governor's School
The Effect of Music Genre on Human Heart Rate, Blood Pressure, and Stress and Anxiety Levels in a Music Therapy Setting

My study investigated the effects of different music genres on humans physiologically and psychologically. Each participant listened to parts of classical, electronic, and rock songs. The purpose of my study was to investigate the possible impact of music therapy as a treatment for stress/anxiety, blood pressure, and heart rate conditions. It was a repeated measures study in which each volunteer rested while listening to my three treatments: Classical, Rock, Electronic, and the control of no music. The treatments were randomly sequenced, with physiological and psychological data collected after each treatment. My results were conflicting in significance but showed potential to support the use of music therapy. It showed trends in lowering

stress/anxiety levels and blood pressure. Pulse increased under every treatment and the control, so it showed no benefit. No one genre proved more beneficial than the others.

Tuteja Hargun, Mills E. Godwin High School

The Effect of Natural Compounds on Glucose Absorption in a Stimulated Digestive System

The purpose of this experiment was to investigate the effects of natural compounds on glucose absorption in a simulated digestive system. This study was conducted due to interest in dietary interventions that may help regulate blood glucose levels. Patients with high blood sugar need to monitor the glucose concentration in their blood. This experiment focuses on how patients may be able to lower their blood sugar spikes after they had a meal. It was hypothesized that the addition of bitter melon extract to a glucose solution would decrease glucose diffusion across a semi-permeable membrane. A simulated digestive system was modeled using dialysis tubing to represent the intestinal membrane. Four treatment groups were tested: bitter melon extract, cinnamon extract, apple cider vinegar, and glucose-only control for comparison. Each dialysis sac was filled with its assigned treatment solution and submerged in distilled water. Benedict's test was performed to the liquid outside the dialysis sac to qualitatively measure how much the glucose travelled out. There were twenty-five trials conducted for each treatment. Compared to the control, bitter melon produced a lower glucose concentration, cinnamon produced a higher one, while apple cider vinegar produced a similar concentration, A chi-square test showed that all treatment groups differed significantly from expected values ($p < 0.05$). These results support the hypothesis and suggest that natural compounds may influence glucose transport across membranes with dietary applications and lead to further studies about the amount of bitter melon needed to significantly lower the amount of glucose in blood.

Uppalapati Kavya, Mills E. Godwin High School

Effect of Synthetic Biopolymer Membranes for Glomerular Filtration

This experiment was performed to investigate how different concentrations of solutes permeate a synthetic membrane, providing a model to better understand glomerular filtration. More than 35.5 million Americans suffer from chronic kidney disease, highlighting the importance of understanding glomerular filtration. Thus, this experiment was conducted to understand how much of the solute albumin will permeate a synthetic biopolymer membrane. The synthetic membrane was created by dissolving agarose, gelatin, and chitosan in heated buffer solution and cooled to form a gel-like consistency. The control of the experiment was 0 mg/mL, while experimental concentrations were 1, 5, and 10 mg/mL. The research hypothesis was that if the concentration of albumin in the donor chamber is increased, the amount of albumin detected in the receiver chamber will increase. Concentration was measured using a Bradford Reagent test and a spectrophotometer and recorded using the absorbance rate. Results demonstrated that increasing albumin concentration led to a concentration-dependent increase in the amount of albumin detected in the filtrate, as evidenced by greater absorbance intensity in the Bradford assay. Statistical analysis using a t-test revealed statistically significant data for all levels of the independent

variable, which supports the hypothesis. These findings help model how protein permeability changes across the glomerular barrier and provide insight into normal versus abnormal kidney function. Further research can be implemented using machine learning models to predict the occurrence of CKD in all ages.

Medicine & Health B (HS MDH-B)

First Place

Osemobor Joshua, Southwest Virginia Governor's School

Analyzing the Effectiveness of Expansion Techniques for Meningeal Tissue

Expansion Microscopy (ExM) is a powerful imaging technique that enhances spatial resolution by physically enlarging biological tissues, enabling detailed visualization without requiring advanced microscopy systems. While ExM has proven effective for many tissue types, its application to highly fibrous and layered tissues remain challenging due to uneven expansion and tissue distortion. This study investigated the effectiveness and efficiency of three expansion methods, standard ExM, Magnify, and a modified version of Magnify for expanding meningeal lymphatic tissue, a structurally complex and clinically significant component of the central nervous system. Brain tissue from rats was used as a comparative control due to its known compatibility with ExM. Tissues were stained, imaged pre- and post-expansion, and quantitatively analyzed using ImageJ, with statistical comparisons performed using one-way ANOVA and follow-up tests. Results showed that standard ExM successfully and reproducibly expanded brain tissue, while meningeal lymphatic tissue exhibited minimal expansion and significant folding. Both Magnify-based methods failed to produce measurable expansion in either tissue type. Statistical analysis confirmed a significant overall difference among methods with a p-value of 0.0160, though only the standard ExM method demonstrated meaningful expansion. Efficiency analysis revealed that Magnify-based methods required fewer materials and less time, despite their lack of effectiveness under the conditions tested. These findings highlight the limitations of current expansion techniques for fibrous tissues and emphasize the need for tissue-specific protocol optimization. Future work should focus on modifying digestion conditions, polymer composition, and tissue preparation strategies to improve expansion uniformity in layered tissues such as the meninges, with potential applications in disease modeling, biopsy analysis, and accessible high-resolution imaging.

Second Place

Sun Amy, Maggie L. Walker Governor's School

Targeting Phosphoinositide Kinase to Improve Pancreatic Cancer Vulnerability to Ferroptosis

Objective: Pancreatic cancer is among the leading causes of cancer-related mortality in the United States. Effective new strategies are urgently needed. Ferroptosis is an iron-dependent, lipid peroxidation-driven form of regulated cell death that may help treat "hard" cancers by bypassing apoptosis resistance and reducing therapy resistance. Interferon-gamma (IFN-γ) signaling plays critical roles in controlling cancer cell sensitivity to ferroptosis. Increased cancer cells' response to IFN-γ enhances their

vulnerability to ferroptosis. Type Iγ phosphatidylinositol phosphate kinase (PIPKIg) has recently been identified as a critical regulator of cancer cell responses to IFN-γ. This study tests whether targeting PIPKIγ increases pancreatic cancer vulnerability to ferroptosis.
Approach: The mouse pancreatic cancer cell line PANC02 was used as a model. PIPKIγ expression was knocked down using specific Small interfering RNA (siRNA), and knockdown efficiency was confirmed by Western blot. Altered responsiveness to IFN-γ was assessed by measuring transcription of IFN-γ target genes using Reverse Transcription quantitative PCR (RT-qPCR). Control and PIPKIγ-knockdown cells were treated with ferroptosis inducers, and cell viability was evaluated using crystal violet staining.
Results: PIPKIγ-specific siRNA markedly reduced PIPKIγ protein levels in PANC02 cells, confirming successful knockdown. IFN-γ target gene expression was strongly increased in PIPKIγ-knockdown cells, indicating enhanced sensitivity to IFN-γ signaling. Consistently, treatment with ferroptosis inducers produced greater cell death in PIPKIγ-knockdown cells compared with controls.
Conclusions: Loss of PIPKIγ increases pancreatic cancer cell sensitivity to IFN-γ signaling and enhances vulnerability to ferroptosis. These findings support PIPKIγ as a potential therapeutic target to improve pancreatic cancer treatment by promoting ferroptotic cell death.

Third Place

Dewan Yana, Mills E. Godwin High School

Preventing Mosquito Puncture and Saliva Transmission: Evaluation of Novel Topical Barriers using Oncopeltus fasciatus

The purpose of this experiment is to test the effectiveness of topical defenses against the puncture and saliva transfer of mosquitoes, by using *Oncopeltus fasciatus* as a model. Mosquitoes are vectors for human diseases that cause millions of deaths annually by transmitting pathogenic saliva. The main defense against them is chemical repellents, which are inefficient, environmentally harmful, and expensive for most where mosquito populations are greatest. If a gel containing virgin coconut oil (VCO), hydrolyzed keratin (HK), and bentonite clay (B) is used, then the number of skin punctures and saliva transmission will be the lowest. Formulas VCO+B, VCO+HK, and VCO+B+HK were applied to artificial skin containing bromothymol blue, a pH indicator. Then it was exposed to an *O. fasciatus* for 10 minutes. No topical gel was the control. The number of punctum and whether saliva transfer occurred was recorded. The results affirmed that the VCO+B+HK barrier allowed for 0 milkweed bug punctures and no saliva transmission, the least out of all barriers. The control produced the highest number of punctures and saliva transfer, followed by the VCO+HK gel, then the VCO+B. The t-tests and chi-squares conducted showcases that the data was largely statistically significant. The results supported the research hypothesis. This was likely due to the combination of the semi-occlusiveness and fatty acid composition of virgin coconut oil, the low-permeability and thickness of calcium bentonite clay, and hydrolyzed keratin's ability to fill microscopic gaps, forming a cohesive and structurally sound barrier.

Honorable Mention

Karim Maryam, Harrisonburg High School

Incorporating Chirality and Conductivity in Scaffolds Toward Functional Tissue Regeneration

Regenerative medicine has made major advances in tissue restoration through stem cell therapies, induced pluripotent stem cells, bioengineered scaffolds to provide an environment native tissue can grow on, and decellularized tissues. Even with these advances, restoring fully functional tissue, especially in excitable tissues such as neural, muscular, and cardiac tissue, remains a challenge due to limited regenerative capacity as scarring takes place, affecting electric and chemical cellular communication. Current scaffolds are either chiral or conductive, not both. Modern scaffolds have shown issues such as only being limited to a few types of tissues, degradation taking too long or quick leading to inflammation or foreign object reactions overall leading to a lack of integration. Without combining these properties, the full potential of regenerating the tissue is not met. This paper investigates the effects of putting chirality and conductivity together to guide cellular migration, alignment, proliferation affect gene expression to regenerate lost tissues and overall create a highly interactive environment. To simulate these conditions, a quantitative image analysis and comparative modeling were performed. Results from the quantitative image analysis demonstrated significant correlations between electrical stability and coordinated migration.

Honorable Mention

Lee Katie, Central Virginia Governor's School for Science and Technology

Which treatment best reduces tooth enamel demineralization: water, xylitol, or mouthwash?

The purpose of this study was to investigate which of the treatments, water, xylitol, or mouthwash, is most effective in reducing the enamel demineralization after immersion in soda. Treatments with water, a 48% xylitol solution, and a Fluoride mouthwash were applied to the teeth according to each product's recommended duration and immersed in soda for 15 days. Before and after the experiment, the surface of each tooth was observed under the Scanning Electron Microscope (SEM), and the mass was measured in milligrams. On average, teeth in the water group (control) lost 8.367mg, the xylitol group lost 51.033mg, and the mouthwash group lost 18.2mg. A one-way ANOVA test determined if there were any significant mean mass differences among the groups. Because the data were found to be significant using alpha = .05 and p-value = .02, Tukey's post-hoc test was conducted with an alpha = .05. The difference was significant between the water and the xylitol, p-value = .02, but not significant between the mouthwash and xylitol, p-value = .06, and between water and mouthwash, p-value = .68. This statistical result did not support the research hypothesis, that if a tooth is immersed in soda for 15 days, then treatment with fluoride content, which is mouthwash, will be the most effective for protecting tooth enamel. Overall, the trend showed that water and mouthwash resulted in a lower mean mass loss than the xylitol group. Statistically, water was significantly more effective in reducing mass loss compared to xylitol, suggesting it reduced demineralization.

Honorable Mention

Worrell Kindred, Chesapeake Bay Governor's School

Fruit Related Pesticide Exposure Effect on Drosophila melanogaster Survival and Reproduction

Pesticide usage has increased exponentially in modern day agriculture to enhance crop production, leading to greater economic profits. Pesticides create DNA lesions that block the DNAs ability to replicate. The purpose of this study is to discover the range of effects pesticide exposure has on *Drosophila melanogaster.* Data will be collected regarding the survival and reproductive rates of the parent generation of fruit flies. In regard to survival of *Drosophila melanogaster*, the organisms thrived for a longer span of time in the organic vials. The statistical t-test of Organic vs. Conventional survival yielded p=0.07, which does not meet the p=0.05 alpha, however suggests significance. The statistical t-test of Organic vs. Conventional yielded p=0.49, showing no statistical difference between the two fruit treatments. The results suggest that the fruits tested do not contain enough pesticide residue to cause statistical significance across trials in regard to *Drosophila* survival and fecundity. It is likely that this means that before harvest and packaging, companies withhold pesticides and/or rinse the potential chemicals from the produce. However, the near significance found in the survival data suggest the fruits may still contain some amount of residue. While consuming sublethal doses of these chemicals may not have immediate effects, an accumulation of small traces of pesticides could still lead to chronic health issues in the future.

Angulo Santiago, Blacksburg High School

The Effect of Weight Training on Sprint Performance in Adolescent Male Swimmers During a three-month period

Sprint swimming performance in adolescent male athletes is influenced by many factors, such as strength, speed, explosiveness, and technique. Resistance training is often implemented in club swim programs in order to improve these attributes. However, its effects on adolescent male performance remain widely debated among coaches. The purpose of this study was to examine whether participation in resistance training during a three-month period yielded greater improvements in sprint performance among adolescent male swimmers compared to no resistance training. This study used a purely observational design involving ten male swimmers between the ages of 13–17. Five of these swimmers consistently participated in resistance training in addition to their regular swim practices, while the other five swimmers did exclusively swim training. Their sprint performance was measured using club meet times in the 50-yard freestyle and 100-yard freestyle. Performance was measured at two different competitive meets, three months apart. Total percent changes in race times were calculated to evaluate their performance. The results indicated that swimmers who participated in resistance training demonstrated slightly better and more consistent improvements in sprint performance compared to those who did not, particularly in the 50-yard freestyle. The swimmers in the resistance training group dropped an average of 2.62% in the 50 freestyle and 2.12% in the 100-yard freestyle. On the other hand, the non-resistance training group added an average of 1.26% in the 50-yard freestyle and dropped an average of 1.24% in the 100-yard freestyle. This

means the resistance training group performed about 3% better overall. However, two independent-sample t-tests were conducted, which indicated that the differences were not statistically significant at the $\alpha = 0.05$ level. Additionally, with several limitations such as small sample size, differences in motivation, and different physical maturity levels, the results could not be generalized.

Boles John, Mills E. Godwin High School
The Effect of Dengue Virus Serotypes on Antibody Response Magnitude.

The main reason for researching this topic was the harm dengue virus infections have been causing millions of people worldwide, as well as the differences between immune serotypes that have not been fully explored. The purpose of this research was to determine which dengue virus caused the strongest and longest antibody response in the infected patients. It was hypothesized that patients infected with DENV-2 would have higher antibody titers compared with those infected with DENV-1, DENV-3, and DENV-4. Since actual patient-level data were not fully accessible, a simulated dataset was generated using published average antibody titers and standard deviations to demonstrate statistical comparisons between dengue serotypes. T-tests were used to show the comparisons between each serotype. The independent variable in this research was the dengue virus serotype, and the dependent variable was the magnitude of the antibody response measured in titers. Constants included the measurement method, patient age range, sample collection procedures, and the dataset source. Statistical analyses like t-tests were performed to determine whether the differences between the serotypes were significant. Descriptive statistics like mean, range, and standard deviation were calculated to study the antibody response trends and patterns within each serotype. The results of this research showed that right after the infection, DENV-3 produced the highest mean antibody titers, followed by DENV-1, DENV-3, and DENV-4. Three years after infection, DENV-2 showed the highest mean antibody titers, followed by DENV-1, DENV-3, and DENV-4. T-tests showed that most of the differences between serotypes were statistically significant, especially when it came to the comparisons involving DENV-4, which always showed low antibody titers. The results of the experiment partially supported the research hypothesis, because while DENV-2 did not have the highest immediate antibody magnitude titers but showed the highest long-term mean magnitude titer response. In conclusion, the structure of the dengue virus serotypes definitely affects both the immediate and long-term magnitude titer response, with DENV-2 producing the highest magnitude response over time.

Chandra Nisha, Mills E. Godwin High School
The Effect of Different Fermentation Starters on the Sugar Content of Apple Juice

The purpose of this study was to determine which of three common fermentation starters: yogurt, sourdough starter, and symbiotic culture of bacteria and yeast (SCOBY), ferments the sugars in apple juice the greatest. The health benefits of fermentation are thoroughly researched. Understanding which foods best ferment various drinks can help society make healthier choices. It's hypothesized that sourdough starter would reduce the sugar content of apple juice the most. To conduct this experiment, the starters were added to three different cups of juice. A fourth cup

of juice contained no starter; this was used as a control to determine the impact of spontaneous fermentation. Sugar reduction by fermentation was measured by changes of pH and density of the juice. The cups of juice were fermented for 48 hours, and the pH was measured and subtracted from the pH of unfermented juice. The density was then calculated. The results showed that the type of fermentation starter had an impact on the sugar content, as the average changes in pH and density were significantly different when analyzed by t-tests, thereby rejecting the null hypothesis, with the exception of density for sourdough vs. control, which was not significant and supported the null hypothesis. The initial hypothesis was not supported as SCOBY, not sourdough starter, reduced sugar content the most. A possible reason why SCOBY reduced the most sugar involves the similarity of the environments of tea and juice, and the production of ethanol.

Luu Brendon, St. Christopher's School

To Grip or Not to Grip: A Study of the Application of Grip Strength on Health

In this study, grip strength will be examined to determine if health markers that have seen impact, such as age, longevity, medical detection, and overall health, can be influenced by grip strength. Should grip strength be used to detect diseases in American medical practice, and if so, should a standardized tool be developed to measure it? This study will experiment with testing individuals with a dynamometer over the course of three days to see how age and grip strength correlate. By utilizing the average grip strength with respect to a certain age range, the study suggests that age has a significant role in grip strength through extensive testing. Limitations to this study followed many other studies in isolating variables. Many variables, such as lifestyle, genetics, injuries, and illnesses, were unaccounted for and should be tested for more accurate results. The importance of this study is to find where grip strength can be used to create impact in the medical field through initial testing to find some emerging patterns. With the need for more tests and experiments through utilizing grip strength, many initial studies have found grip strength to be significant to overall health, longevity, and delaying the progression of certain neurological diseases.

Mudimbi Samhita, Mills E. Godwin High School

The Effects of Different Nutrients' Efficiency in Stomach Lining Protection

The purpose of this experiment was to investigate the effects of different types of nutrients on their ability to protect the stomach lining from the harsh stomach environment. The primary degradation of the stomach lining occurs due to stomach acid and a bacterial strain known as *Helicobacter pylori* (often referred to as *H. pylori*). These can cause gastric ulcers and gastritis; two common diseases found in adults aged 40 and above. When conducting this experiment, different foods were used for certain nutrients that they contain. Cabbages, which have the amino acid glutamine, bananas, which have fibers, and yogurt, which has probiotics. All of these nutrients possess the capabilities to protect and support the immune system and gastrointestinal health. It was hypothesized that bananas would be able to preserve the stomach's lining best due to their high concentration of fiber. The mean was calculated from the data points and was found to be highest for glutamine (-2.063), showing it shielded the artificial stomach lining samples the least. The mean was found to be lowest for

samples soaked in banana and simulated stomach acid solution (-1.007). Due to multiple human errors, most likely in weighing the samples, the null hypothesis was not rejected. Although the results were found to be insignificant by the t-tests, the means still show valuable results, displaying that the fibers found in bananas can aid in the protection of the stomach lining from stomach acid.

Padala Abhinav, Mills E. Godwin High School
The Effect of Natural Substances on Cholesterol Levels

The purpose of this study was to investigate the immediate impact of natural substances on cholesterol levels (spot intensity and retention factor). Recent studies showed that ginger, green tea, and policosanol all have a significant impact on the cholesterol levels within the body. On the other hand, other studies contradict each other and believe that there is no direct correlation between dietary cholesterol and blood cholesterol levels. Additionally, dietary cholesterol is the cholesterol you intake on a daily basis by eating food. The reason why all of the variables can decrease cholesterol levels is that they have properties that break down blood cholesterol within the body. Twenty-five trials were performed for each independent variable, where 25 milligrams of cholesterol, 25 milligrams of the natural substance, and 25 milliliters of ethanol were all mixed. After the data were collected, t-tests and chi-square tests were performed to compare the control group to the other natural substances. The t-tests were conducted at the significance level of 0.05, and the T-test showed that the data collected was insignificant except for green tea. Additionally, all of the chi-square tests came back positive. The reason why some of the results are insignificant is due to human error when calculating the retention factor, and the process of measuring specific amounts of substances with slightly inaccurate balances.

Reyes Alessandra, Mills E. Godwin High School
*The Effect of Oil Type on Amount of Trans Epidermal Water Loss (TEW*L).

The purpose of this study was to investigate the effects of oil type on trans epidermal water loss. The skin is the outermost organ of the body, and it's the protective layer to the outside world. To keep the skin strong, the skin barrier needs to retain moisture. Oils provide a seal between the stratum corneum and the environment to prevent evaporation from the skin, thus retaining moisture. This study aimed to find the most effective TEWL-preventing oil. The research hypothesis was "If the oil is more occlusive or heavier, then there will be less trans epidermal water loss." Gelatin molds were created using gelatin packets, 100 petri dishes were filled with gelatin, and 5mLs of oil type (sweet almond, coconut, or rosehip) were placed on top of each petri dish, excluding the control dishes. Coconut vs. almond oil, rosehip vs. almond oil, and all t-tests compared to the control were statistically significant. This signaled that the results were due to the independent variable and not chance. The t-test between rosehip oil and coconut oil was statistically insignificant, which meant the results were likely due to chance and not the independent variable. These results were most likely observed due to the molecular structure of the oils; although coconut oil is generally the most occlusive oil, its molecular structure caused it to behave differently when interacting with the gelatin surface. The almond oil also responded differently to the gelatin surface. The results of the coconut and rosehip oil test were likely due to sources of error.

Verghese Vivien, Mills E. Godwin High School
The Effect of Moisturizer Humectant on Moisture Retention of Skin

The purpose of this experiment was to determine the effect of various humectant types on the moisture retention of skin. Recently, the spike in interest in skincare products among consumers and the prevalence of dry skin conditions supports an increased need to find the highest performing humectant for moisturizer. Skin models were made out of gelatin in petri dishes and then applied a humectant: hyaluronic acid, panthenol or glycerin, or left untreated as a control. The weight of each dish was recorded before and after the sitting period, and the change in weight was calculated to determine the moisture content lost for each humectant. It was hypothesized that if hyaluronic acid is applied to the skin model, then it will retain the highest moisture content. The comparison of the mean of the results revealed panthenol retained the most moisture, losing 0.36 g, followed by hyaluronic acid at 0.72, glycerin at 0.76 and the untreated control at 0.88. A t-test was done with a 0.5 level of significance on the data, and the data was statistically significant for the panthenol group but not statistically significant for hyaluronic acid or glycerin groups. These results did not support the research hypothesis. An explanation for these results could include panthenol's ability to alter the protein structures of the skin which, combined with its hygroscopic properties, result in long lasting hydration to the stratum corneum of the skin. Studies on the mechanisms of types of humectants and their performance are valuable to both manufacturers and consumers to support hydrated and well-functioning skin.

Medicine & Health C (HS MDH-C)

Cancer Research Award
First Place

Goel Ahana, Mills E. Godwin High School
Evaluating Tinospora cordifolia and Gemcitabine's Combined Effects on Pancreatic Cancer

The purpose of this experiment was to test whether combining Gemcitabine and *Tinospora cordifolia* produces a significant inhibitory effect on pancreatic cancer cell growth compared to Gemcitabine alone. While the five-year survival rate for pancreatic cancer remains near 10%, Guduchi (*Tinospora cordifolia*) contains bioactive Phyto-compounds like alkaloids and glycosides that exhibit anticancer activity by inhibiting growth and activating apoptosis. In this study, Gemcitabine and Guduchi solutions were formulated and applied to pancreatic cancer cells. Following 72 hours of incubation, cells were stained with MTT dye and analyzed via a spectrophotometer to measure absorbance at 560 nm. The control consisted of 32 wells receiving no treatment. It was hypothesized that the combination of 10 µg of Guduchi and 2 µM of Gemcitabine would result in the lowest cell proliferation. The results supported the hypothesis, as the 10 µg Guduchi and 2 µM Gemcitabine group exhibited the lowest proliferation rate. Statistical analysis via t-tests were conducted, with 22 tests being statistically significant and rejecting the null hypothesis. These results suggest that Guduchi Phyto-compounds may sensitize cancer cells, enhancing the DNA-damaging mechanisms of

Gemcitabine. This research provides a foundation for investigating specific mechanisms used to enhance the anti-cancer effects of different chemotherapeutic medicines and testing lower concentrations of Guduchi to optimize treatment efficacy.

Dr. Jerome Parsons Award for Clinical Dermatology
Second Place
Judy Olivia, Central Virginia Governor's School for Science and Technology
Trapping Water, Not Skin an In-Vitro Study of Hyaluronic Acid and Occlusive Moisturizers

The purpose of this study was to investigate the effects of topical treatment type and application time on hydration in an in-vitro skin model. Four treatment conditions were evaluated: a control (no occlusive), baby oil, Vaseline, and combined baby oil and Vaseline treatment. Hydration levels were measured at multiple time intervals following application using a standardized digital hydration assessment method. Mean hydration values were calculated to examine overall trends across treatments and time points. All groups began near 81–84%. Control declined sharply after 2 hours (24.00% at 6 hours, 0% by 8 hours). Vaseline decreased gradually (49.33% at 10 hours), Baby Oil dropped to 25.00%, while Both remained stable near 76%. A two-way analysis of variance (ANOVA) revealed significant main effects of topical treatment and time, as well as a significant interaction between treatment and time ($p < .01$, $\alpha=.05$). Results showed that hydration varied significantly as a function of both treatment type and time. Treatments containing occlusive agents produced higher mean hydration values than the control, with the combined treatment yielding the greatest hydration retention at extended time points. These findings demonstrated that both the formulation of topical treatments and the duration of application significantly influenced hydration outcomes. The research hypothesis, which predicted Vaseline providing the best environment, was partially supported, as combined treatment provided the best environment; however, Vaseline showed better results than the control. Overall, this study highlighted the importance of treatment composition and application duration in maximizing hydration retention in skin models.

Third Place
Kirby Charlotte, Chesapeake Bay Governor's School
Football Player Hydration and Readiness During High Temperature Summer Practices

Rising temperatures are impacting youth sports, especially late summer. There is growing concern that climate driven heat increases are intersecting with known physiological vulnerabilities in adolescent athletes. The purpose of this study is to evaluate the hydration status of high school football athletes by examining their self-reported urine color and fluid intake over a practice week in the months of June, July, August, September, and October. The month of October, a non–heat stress period was used to compare the summer data. Hydration assessments revealed that multiple athletes were severely dehydrated every day of the study period. During the summer months, an average of 5–6 players per practice fell into the "Bad" hydration category, indicating severe dehydration according to the VHSL guidelines. Although the number of dehydrated athletes per practice did not reach statistical significance when compared

across months, the practical implications are substantial. It only takes one severely dehydrated athlete practicing in extreme heat to trigger a life-threatening medical emergency. Ultimately, the findings of this study underscore the urgent need for stronger hydration education, consistent monitoring, and strict adherence to heat safety protocols in high school athletics.

Honorable Mention

Bag Sreetoma, Mills E. Godwin High School

The Effect of Different Cancer Cells on their Reaction to Gemcitabine

The purpose of this experiment was to determine the effect of different cancer cells on their cell viability absorbance when introduced to gemcitabine to understand which one it is most effective on. Pancreatic, breast and ovarian cancer are harmful diseases which cause suffering to many and were used in this experiment because all three are affected by gemcitabine. All three types of cancer cells were treated with 5 micro molars of gemcitabine and incubated for growth. The controls in the experiment were untreated pancreatic, breast and ovarian cancer cells. Previously, it was hypothesized that if pancreatic cancer cells are used with gemcitabine, then the gemcitabine will kill the greatest number of viable cells. The results of the experiment revealed that gemcitabine, on average, decreased cell viability in absorbance units (AU) by 2.37 AU, while pancreatic cancer cells decreased 0.831 AU, on average, and breast cancer cells decreased 0.032 AU, on average. A t-test was performed on the data, and each IV-level comparison was statistically significant, but the results did not support the research hypothesis. It is believed that the results were because pancreatic cells are more resistant to gemcitabine than ovarian cancer cells causing the ovarian cells to be far more affected. Further research could be conducted by experimenting to find the optimum amount of gemcitabine for the three cancer cells. Additionally, further study could also be the effect of a gemcitabine combination with another chemotherapy agent on one of all three cancer cells.

Honorable Mention

Dung Hayleii, Mills E. Godwin High School

The Effect of Natural Liquids on Gelatin Solidification (Coagulation)

The purpose of this experiment is to examine the effects of natural liquids on gelatin and decide which is optimal for inhibiting gelatin solidification. This is to benefit people who need cheaper alternatives to obtain anticoagulants and pharmaceuticals in understanding the biological agents of these liquids towards medicinal advances. Cups of water, pineapple juice, pomegranate juice, and grapefruit juice were mixed with unflavored gelatin powder. They were refrigerated for 60 minutes and taken out to determine solidification state. The control in this experiment was water. It was hypothesized that if pineapple juice is mixed with unflavored gelatin powder, then it will have the most unsolidified gelatin. A chi-square test was performed on the data at a $\alpha = 0.05$, and it revealed that water, pineapple juice, and pomegranate juice to be significant, but grapefruit juice was insignificant. The results showed pineapple juice, pomegranate juice, and grapefruit juice to have more inhibited solidification than the control of water. Pomegranate juice had the most unsolidified gelatin. The research hypothesis was not supported as there was a possible source of error of pineapple juice

not having a constant cooling rate. Pomegranate juice likely performed the best due to its proteolytic and acidic capabilities. This research could lead to further studies exploring natural foods such as turmeric, instead of natural liquids, to investigate and maintain blood flow, including its effectiveness and efficiency compared to natural liquids.

Honorable Mention

Madaan Arjun, Mills E. Godwin High School

The Effect of Withania somnifera on Girardia tigrina Regeneration

The purpose of this experiment was to test the effects of the Ayurvedic homeopathic treatment of *Withania somnifera* ("ashwagandha" or "Indian ginseng") on the regeneration of *Girardia tigrina*, a type of planarian flatworm with regenerative properties that make it an excellent model of stem cells. Stem cells have been recently used as a treatment in cancer and neurodegenerative diseases, and ashwagandha and Ayurvedic homeopathic treatments (including ashwagandha) have also been studied for any regenerative properties. As such, any demonstrated effect of ashwagandha on these flatworms could provide valuable insight. The 100 *Girardia tigrina* were fed a collective total of 0.2 grams of hard-boiled egg yolk and were then placed into petri dishes with 10 mLs of extract solution for one week. The regeneration was calculated by the relative percentage change between the initial and final measurements. It was hypothesized that if the concentration of *Withania somnifera* extract in the *Girardia tigrina* water was 0.5% by volume, then the *Girardia tigrina* would exhibit the most regeneration. The results showed that 0.5% caused the optimal regeneration amount, which supported the research hypothesis. The results were neither significant nor insignificant, with three t-tests being significant, and three being insignificant. A potential explanation for the maximum regeneration at 0.5% may be due to the steroidal structure of ashwagandha, allowing for increased regeneration, but there was extreme death at the 1% concentration, highlighting a potentially lethal dose. Future investigations may include the testing of different substances such as turmeric.

Eesha Pellreddy, Mills E. Godwin High School

The Effect of Anastomosis Angle on Peripheral Vascular Graft Effectiveness

The purpose of this experiment was to determine whether the anastomosis angle influences vascular graft effectiveness and performance. Peripheral vascular disease is a health complication that affects many individuals globally. One of the many effects of this disease consists of the buildup of plaque and restricting free blood flow through arteries in the vascular region. Peripheral vascular grafting is a surgical procedure conducted to redirect the blood flow past the blockage to reinstate proper circulation in that area. Surgical grafts are attached at certain anastomosis angles to create the most effective bypass. In this experiment, 30-, 45-, and 60-degree angles were tested. There was no specific control to this experiment, due to the prerequisite of an angle's necessity to be tested to reroute the blood flow. It was hypothesized that if the 45-degree angle graft was constructed on the blocked artery to bypass the blood flow, it would produce the highest fluid flow rate. The outcome suggested that the 30-degree angle had the most optimal blood flow rate, at 4.0 ml/s. Therefore, the hypothesis was not supported by the research. A t-test was performed on the data which demonstrated

that the results were statistically significant. These results were most probably achieved due to the 30-degree angle, which created the ideal balance between turbulence and blood flow. The acuteness of this angle allowed for proper blood distribution without any disturbances in the graft. The angle created a balance of wall shear stress on the walls of the artery, which is crucial for anastomosis success. This research can lead to further studies that can investigate the wall shear stress of the arterial wall created by anastomosis.

Garza Mirabella, Blacksburg High School

The Influence of Car Seat Carrying Technique on Lower-Limb Symmetry During Gait.

Many caregivers carry infant car seats daily, often using one arm. This uneven load may place a strain on lower extremities over time. While previous research has shown that external load carriage alters gait mechanics, little research has examined whether how the load is carried influences lower-limb symmetry. This study investigated whether carrying technique (extended arm versus flexed arm) affects limb symmetry during walking with a rear-facing infant car seat. Understanding whether carrying technique influences gait symmetry may help inform safer carrying practices for caregivers.

A secondary analysis was conducted using biomechanical data collected from 75 healthy adult participants completing 338 walking trials across an EMED pressure plate walkway while carrying a 10 kg weighted car seat. Limb Symmetry Index (LSI) for contact area, contact time, and peak force was calculated for each trial using data collected by the walkway. Statistical models were used to evaluate the effect of carrying technique while accounting for repeated measures within participants and controlling for gait speed, sex assigned at birth, and body mass index.

Carrying technique was not a significant predictor of peak force or contact time symmetry. For contact area symmetry, carrying technique approached significance ($p = 0.090$), with flexed arm carrying associated with slightly greater asymmetry. Across all measures, LSI values remained close to 100, suggesting that participants maintained relatively symmetrical gait patterns regardless of technique.

These findings indicate that while carrying technique may influence plantar load distribution, it does not substantially alter overall force or timing symmetry during walking.

Jiyas Eshal, Mills E. Godwin High School

Different Sunscreen Brands on UV Protection with Stimulated Sweat

The purpose of this experiment was to determine the effects of different sunscreen brands on the time protected from UV rays when sweat was stimulated. In recent times, sunscreen has become a prevailing way of protection against destructive rays. Sunscreen was typically used in various outdoor activities, such as sports, gatherings, and walks. UV beads were treated with a coating of either CeraVe, Neutrogena, or The Ordinary. The beads were measured and coated for 24 hours, and then a before-and-after rating was measured. The control in the experiment was no sunscreen. It was hypothesized that Neutrogena would have the highest rating among the other various sunscreens tested. The results revealed that UV beads treated with Neutrogena had the highest median, which was 3. A chi-square was done on the data, and it revealed that the data was significant for the expected vs Neutrogena, expected

vs CeraVe, expected vs The Ordinary, and the expected vs the control. The results did support the research hypothesis. It was believed that the results are since Neutrogena was SPF 70, and compared to the other sunscreens, due to its higher SPF number, it blocks out the rays well. This research could lead to further studies that investigate how sweat and chemicals react together.

Kaur Ajooni, Mills E. Godwin High School

The Effect of Various Senolytic Compounds on Drosophila melanogaster Lifespan

Chronic diseases are the leading cause of death in the United States as a primary result of aging which is most substantially caused by the accumulation of senescent cells in the human tissues. To eradicate these cells from the body, senolytic agents have been discovered that target and kill senescent cells. The purpose of this experiment is to determine which senolytic compound results in the longest lifespan of *Drosophila melanogaster*. By concluding which senolytic compound is most effective in killing senescent cells, therapies can be developed to allow a healthier life for the elderly. The hypothesis for this experiment was that if various senolytic compounds are tested, then Fisetin will extend the lifespan of *Drosophila melanogaster* the most. The control group for this experiment was no senolytic compound. Fly food mixed with each senolytic compound was placed in four different vials, followed by anesthetizing fruit flies and separating them by gender. In each vial, 25 male flies were placed. Every day, the researcher checked to see if any had died, and if so, recorded their lifespan. Based on the data collected, Fisetin resulted in the longest average lifespan, with a mean lifespan of 24 days, which supported the hypothesis. The data for Fisetin was also the only level of independent variable that had statistically significant data, with a t-test value of 3.674. Fisetin likely extended the lifespan of fruit flies the most, because the senolytic compound was able to disrupt anti-apoptosis pathways and kill senescent cells in the tissues.

Patil Aryan, Mills E. Godwin High School

The Effect of Caffeine Concentrations on Physarum polycephalum Growth

This study investigated the effect of various caffeine concentrations on the neurological abilities of slime molds, *Physarum polycephalum*, organisms known for their extraordinary intelligence as a single-celled organism. Caffeine, which has been quoted as a ‘miracle drug’, is known for enhancing cognitive functions, while also having the ability to ward off certain neurodegenerative diseases. Understanding how caffeine influences cognitive abilities could have implications in the neurological field, finding ways to enhance performances, or cognitive abilities overall.

It was hypothesized that a concentration of 10 mg/L would yield the highest cognitive abilities, measured in the area covered by slime molds, compared to other groups. The study employed a control group of 0 mg/L, and other experimental groups, (1 mg/L, 5 mg/L, and 10 mg/L). Slime molds were observed for three days, and data was recorded every 24 hours by measuring the area covered via the grid method.

The results indicated that the 10 mg/L concentration enhanced cognitive abilities through the area covered compared to the control and other experimental groups. However, the 1 mg/L group had erred readings, which was possibly due to human error during the experiment. These findings suggest a dose-dependent relationship between

caffeine concentrations and the neurological abilities of slime molds, positively supporting the hypothesis.

These results align with existing research on caffeine's bioactive properties, reinforcing its therapeutic potential. However, environmental variability, caffeine solubility, and measurement inconsistencies may have influenced outcomes. Future research should explore the molecular mechanisms behind caffeine's effects and investigate its application in other neurological models.

Poquis Liana, Mills E. Godwin High School

The Effect of Habitual Heat Exposure on the Integrity of Nickel Titanium Arch Wires

Although nickel titanium arch wires are an immensely efficient way to move teeth during orthodontic treatment, external factors like temperature can affect the integrity of the wires among orthodontic patients. The purpose of this experiment was to determine if various levels of habitual exposure to high temperatures affect the integrity of nickel titanium wires. The nickel titanium wires were split into four groups- 42 cycles, 21 cycles, 5 cycles, and 0 cycles as a control. Each 'cycle' consisted of one minute inside an electric oven set to 170 °F and one minute of cooling outside. After each wire went through their assigned cycles of habitual heat exposure, they were bent consecutively at a 180° angle until breakage occurred. It was hypothesized that 42 cycles of heat exposure would yield the lowest average bends until breakage. The results revealed that 42 cycles had the lowest average bends until breakage (8) and 0 cycles had the highest average bends until breakage (15). A t-test was conducted which showed that the data was not significant for 0 cycles vs 5 cycles but however was significant for 0 cycles vs 21 cycles, 0 cycles vs 42 cycles, 5 cycles vs 21 cycles, 5 cycles vs 42 cycles, and 21 cycles vs 42 cycles. Most of the results supported the research hypothesis. It was hypothesized that the results were due to a permanent strain induced on the wires by the high temperature. This research could contribute to a further study of how distinct levels of temperature affect nickel titanium wire rather than habitual exposure.

Sankepalli Ananya, Mills E. Godwin High School

The Effect of Plant Extracts on the Moisture Loss of Gelatin-Based Films

Skin, the largest organ of the human body, is constantly exposed to injuries and infectious agents that can compromise healing. Gelatin-based films are widely used as wound dressings due to their biocompatibility and hydrophilic properties, but they often lack strong moisture retention and antimicrobial activity. This experiment investigated the effect of plant extracts, including aloe vera, green tea, and turmeric, on the moisture retention of gelatin-based films. The independent variable was the type of extract added, while the dependent variable was the amount of moisture loss over eight hours, measured every two hours. Films were prepared by dissolving gelatin in distilled water with glycerol, adding specific plant extracts, and drying the films in petri dishes. Results showed that turmeric extract exhibited the least moisture loss, followed by the control, aloe vera, and green tea extract, contradicting the initial hypothesis that aloe vera would retain the most moisture. Statistical analysis using t-tests indicated that some differences between extracts were significant, particularly for turmeric, highlighting its potential to enhance gelatin film performance. The findings suggest that plant extracts

can influence the water retention capacity of gelatin films, which is crucial for maintaining a moist environment to promote wound healing. Future research could explore additional plant extracts, combinations of extracts, and other dressing types, as well as antimicrobial and mechanical properties. Overall, this study supports the potential of natural, cost-effective, and biodegradable wound dressings to improve healing outcomes and offers a foundation for further development of plant-based wound-care materials.

Unnithan Bhama, Mills E. Godwin High School
The Effect of Processing Antioxidant-Rich Foods on Antioxidant Level

The experiment was conducted to compare the results of antioxidants in raw foods compared to foods that had been processed in a typical consumable manner. The results for the former were obtained from a previous study completed with the same independent variables and assay. The assay used in both experiments was chemiluminescence which was researched to be an effective method of identifying the level of antioxidants in a substance due to the nature of the reaction. Chemiluminescence is an oxidative reaction which antioxidants should subsequently counteract, therefore when the reaction subsides faster, it is known that the level of antioxidants is higher. The application of the results is focused on daily lifestyle and food health; although raw foods are generally accepted to be healthier for consumption, it is unrealistic to not prepare foods as part of dishes, which includes processing the food through a variety of methods. For this experiment, fruits were cooked into a jam and vegetables were simmered, applying common methods of processed consumption for these foods. Then subjected to chemiluminescence, an oxidative reaction, which should be counteracted by the presence of antioxidants. The expected outcome was that the processed foods would show lower levels of antioxidants compared to the original raw foods, however, there might be spikes in levels of previously low ranked foods because of heat activation of other antioxidants and enzymes. The p values of the results were all less than 0.05 showing a significant difference from their original values, however, blueberries showed a decrease in time rather than an increase and grapes showed no visible chemiluminescence at all.

Microbiology & Cell Biology A (HS MCB-A)

First Place
Ali Saad, Blacksburg High School
Investigating Diurnal Oscillations of Cell Division Timing in Stentor coeruleus

Circadian rhythms have been well characterized in almost every major biological kingdom; however, they are still elusive and poorly understood in unicellular organisms. Previous work in unicellular organisms has shown oscillations in cellular behavior; however, this work was performed decades ago with equipment that is not commercially available. All modern commercially available circadian behavioral equipment is designed for mammals and is unsuitable and unadaptable for work on unicellular organisms. In this study, we explore behavioral diurnal rhythms in the unicellular ciliate Stentor Coeruleous, demonstrating diurnal oscillations in cell division behavior, a canonically circadian trait. We also developed an incubation and imaging chamber that

allows us to capture video of unicellular organisms for extended periods of time under constant conditions and with oscillating day/night cycles. This imaging method will allow us to perform full circadian assays not just on cell division behavior, but also in cell mobility, phototaxis, photo accumulation, and avoidance behavior. It is also translatable to other unicellular organisms, allowing us to perform assays not just in *Stentor* species, but in other large unicellular organisms or plankton as well.

Second Place

Singhal Aditya, Xing Ethan, Maggie L. Walker Governor's School

In Vitro Study of Hydrogen Sulfide Therapy as a Treatment for Cardiomyocyte Senescence in Hypertensive Cancer Survivors

Anthracycline chemotherapy, particularly doxorubicin (DOX), causes cardiotoxicity and, later, cardiomyopathy, with risk significantly increased in patients with chronic hypertension. This study investigated the effects of DOX and angiotensin II (ANGII) induced hypertensive stress on cardiomyocyte senescence and tested hydrogen sulfide (H_2S) as a therapy. AC16 cardiomyocytes were treated with DOX (3 μM), ANGII (200 μM), and the H_2S donor GYY4137 (100 μM). Cell viability (MTT assay), ROS generation (CM-H_2DCFDA fluorescence test), and senescence-associated β-galactosidase (SA-β-gal) expression were assessed. DOX reduced cell viability to 87%, which declined to 59% in hypertensive conditions ($p = 0.00135$). H_2S restored it to 96.1% without ANGII and 79.7% with ANGII ($p = 0.000538$). ROS levels increased from 1,074,385 relative fluorescence units (RFU) in healthy cells to 1,590,371 RFU with combined DOX and ANGII treatment ($p = 0.03132$). H_2S reduced ROS to 1,269,223 RFU ($p = 0.0451$). SA-β-gal staining showed the same trends, confirming senescence or the lack thereof. Future studies could expand senescence profiling by using additional biomarkers or investigate H_2S-mediated mitochondrial bioenergetics to clarify its potential. These findings demonstrate that hypertension exacerbates anthracycline-induced cardiomyocyte senescence and identify H_2S therapy as a statistically significant treatment for hypertensive cancer survivors.

Third Place

Shen, Alexander, Mills E. Godwin High School

The Effect of Different Cytokines on Breast Cancer Ferroptosis

Ferroptosis is an iron-dependent regulated cell death caused by lipid peroxide accumulation. It is a new and exciting type of cell death that can be utilized in developing new therapies to combat highly metastatic and aggressive cancers like triple-negative breast cancer. The purpose of this study was to determine how different cytokines could influence ferroptosis in MDA-MB-231 breast cancer cells when induced by the small lethal compound RSL3. This research is highly important and valuable because immune signaling molecules like interferon-gamma and interleukin-6 may increase the effectiveness of ferroptosis-based treatments and contribute to the development of new therapies. It was hypothesized that combining the small lethal compound RSL3 and interferon-gamma would induce the highest level of ferroptosis, while interleukin-6 would have a weaker or no effect due to its pro-surviving signaling role in the body. A no-treatment control group was created to establish a comparison for cell viability with the other independent variables and to validate the significance of the results. The

results showed that treatments involving RSL3 greatly reduced the cell survival rate when compared to the untreated control. The combination of RSL3 and interferon-gamma yielded the lowest absorbance values, indicating that it induced the most ferroptosis when compared to the other independent variables. On the other hand, cytokine-only treatments were proven to be not statistically significant at a significant level of 0.001. These findings from the study support the hypothesis that interferon-gamma would strengthen the potency of RSL3 in inducing ferroptosis in triple-negative breast cancer cells.

Honorable Mention

Dawkins Elizabeth, Chesapeake Bay Governor's School

Investigating the Abundance and Diversity of Vibrio Bacteria in the Eastern Oyster, Crassostrea virginica

In the past few years, many outbreaks of seafood-borne illnesses in humans have been linked to *Vibrio* bacteria*,* which are sometimes present in oysters (CDC, 2024). As oysters filter water, they concentrate *Vibrio* in their tissues, so consuming raw oysters puts individuals at risk. *Vibrio* grow best in low salinity, warm water and they live in marine and estuarine waters. This study investigates the diversity and abundance of *Vibrio* in two genetic lines of *C. virginica* grown at two locations in the Chesapeake Bay to better understand the dynamics of *Vibrio* populations. The independent variables were the different sites where the oysters were grown, Big Island and Little Wicomico; and the different lines of oysters XB and LOLA. The dependent variables are the abundance and diversity of *Vibrio* spp. found in the oysters. XB oysters had a higher diversity of *Vibrio* species than LOLA oysters. In BI June 2023, there were 7 *Vibrio* species in XB oysters, and 6 *Vibrio* species in LOLA oysters. In LW June 2023, there were 8 *Vibrio* species in XB oysters, and 3 *Vibrio* species in LOLA oysters. Between the locations, BI had 9 species of *Vibrio* bacteria, whereas LW had 8 *Vibrio* species. Notably, the XB oysters exhibited greater *Vibrio* species diversity compared to the LOLA oysters across both locations, suggesting that genetic line may influence microbial diversity within oyster tissues. Additionally, the presence of pathogenic species such as *V. parahaemolyticus* and *V. vulnificus* highlights the potential public health risks associated with consuming raw oysters.

Honorable Mention

Ganesh Taarun, Thomas Jefferson High School for Science and Technology

Investigating Ribosome Interactions with Mitochondrial Receptors and Chaperones with the NAC complex

The nascent polypeptide-associated complex (NAC) is a conserved ribosome-bound factor that monitors newly synthesized proteins and prevents their mistargeting during translation. NAC also plays a critical role in promoting the binding and recruitment of nascent chain processing enzymes and targeting factors. However, whether NAC also facilitates binding of mitochondrial protein chaperones and receptors remains unclear. To address this question, NAC was isolated and purified using affinity-based biochemical techniques and analyzed using SDS-PAGE to confirm purity. *In vitro* binding assays were then conducted to test whether NAC promotes binding of selected mitochondrial-associated proteins, including cleaved Tom20, Tom70, and Tom34. Co-

purification and ultracentrifugation approaches were used to assess interactions under controlled *in vitro* conditions. Binding was evaluated qualitatively by SDS-PAGE analysis of co-migrating protein bands. These assays showed that the mitochondrial receptors Tom20 and Tom34 can associate with the ribosome; however, their binding was not influenced by the presence of NAC. Overall, the results indicate that NAC did not affect ribosome-associated binding of the mitochondrial receptors tested under the experimental conditions used. These findings suggest that mitochondrial receptor recruitment to the ribosome may occur independently of NAC and provide a foundation for future studies to identify additional factors that govern co-translational mitochondrial targeting.

Honorable Mention

Manchu Lakshmi Sriansha, Mills E. Godwin High School

The Effect of Composts on the Voltage Output of a Yeast Based Microbial Fuel Cell

Recent studies have shown that there has been a lack of electricity throughout the world, specifically in remote areas. The purpose of this experiment was to determine the effect of different composts on the voltage output of a yeast based microbial fuel cell (MFC). A yeast based MFC was created and treated with 25 g of vermicompost, leaf litter compost, and food scrap compost. It also was not treated with any compost to compare the data from each compost against stable results. The voltage output of each MFC was measured every 5 minutes for 30 minutes using a multimeter in volts and recorded. It was hypothesized that yeast based MFC's treated with vermicompost would have the highest voltage output. The results of the experiment revealed that yeast based MFC's treated with vermicompost had the greatest voltage output and MFC's treated with leaf litter compost produced the least voltage. A t-test was conducted on the data and the data showed to be overall significant with the exception the control versus leaf litter compost. The results supported the research hypothesis. It is believed that the results of this experiment are caused by the composition of each compost. Microbial activity and organic carbon increase the voltage output of an MFC and are both aspects that vermicompost contains. This research could lead to further studies related to performing changes in MFC designs to advance the operating conditions including efficiency and the consistency of the voltage produced.

Ghosh Siddharth, Yorktown High School

The Effect of Plant Species on the Antibiotic Production Viability of Bacteria in Loosely Adhering Soil: A Spatial Microbial Analysis

Antibiotic resistance is becoming a huge problem in modern-day medicine, creating the need to find new antimicrobial compounds in soil. The main purpose of this study was to assess the antibiotic production potential of bacteria in the loosely adhering soil of plant roots, which surrounds the root-adjacent rhizosphere. Bacterial colonies were isolated from the loosely adhering soil of two plants, *Morus rubra* and *Catalpa speciosa*, and bulk soil. The colonies were grown on plates with lawns of pathogen relatives *Escherichia coli, Pseudomonas putida,* and *Staphylococcus epidermis* to measure zones of inhibition. The hypothesis, which stated soil bacteria from *Morus rubra* would produce the greatest zone of inhibition, was rejected, and the null hypothesis was accepted, because there were no zones of inhibition against *P.*

putida or *E. coli*. *S. epidermis* did not form complete lawns due to coming from an unviable sample, and contamination colonies were present, so contamination, soil colony, and lawn size were measured. This created a second purpose for this study: to determine what factors influence the growth of the incomplete *S. epidermis* lawn. For the *S. epidermis* plates, *Morus rubra* had the largest colonies, and the bulk soil plates had the most contamination. An ANOVA test produced p-values of 0.192408 for lawn size, 0.024757 for colony size, and 0.001391 for contamination size, the latter two being statistically significant. Logarithmic and decision tree regression was used to determine the effect of colony and contamination size on lawn growth, producing respective R^2 values of 0.687 and -41.213. There is an evident decrease in lawn size as colony size increases, but contamination and colony size are not good predictors of lawn growth, indicating that direct spatial competition from soil colonies can have a correlated, but not causal, relationship with the lawn growth of an unviable sample. Since there were no zones of inhibition, this study could indicate that loosely adhering soil does not possess the same pathogen inhibition potential as rhizosphere soil, but more testing is needed to confirm this.

Kulkarni Alisha, Mills E. Godwin High School

The Effect of Essential Oils on the Browning of Malus domestica. (Apple)

The objective of this experiment is to determine whether essential oils can impact the browning of apples. In the past few years, it has been evident that essential oils are changing the agricultural industry specifically in food preservation. They are being widely recognized for their addition to food packaging and ability to fight off bacteria, but they can also help inhibit browning. Thus, it was hypothesized that apples treated with Thyme oil will exhibit less browning. Apple wedges were sprayed three times with either Thyme, Rosemary, or Clary Sage oil. The apples were left with oil for two hours and the before/after pictures were analyzed through ImageJ. The control for this experiment was no oil as its absence provides a baseline for comparison. The results indicate that apples treated with essential oils browned more than the apples treated with nothing. After a t-test was conducted on the data, it was revealed that the data was significant for all comparisons. The research hypothesis was not supported by the results. The results are most likely due to the slightly dark color of the essential oils that the apple absorbed. This experiment could lead to further research on how essential oils can maybe control browning in different fruits, or if different oils would be better suited for reducing browning.

Sambangi Saanvi, Mills E. Godwin High School

The Effect of Different Mushroom Supplements on Milk Coagulation

The purpose of this experiment was to find the effects of different mushroom supplements on milk coagulation. Recently, mushroom supplements have become increasingly popular in natural and home remedies. Where mushrooms have been scientifically proven to improve health, mushroom supplements and their dosages are an untested, underregulated field. In fact, certain mushrooms that have become popular supplements have been noted to decrease platelet aggregation, stopping the blood from clotting. To assess the potentially dangerous blood thinning effects of the mushroom supplements, milk was introduced to solutions of reishi mushroom with

vinegar, lion's mane mushroom with vinegar, and wood ear mushroom with vinegar. The research hypothesis was that if reishi mushroom is introduced to a vinegar and milk mixture, then it will produce the least curd, or coagulated milk. The control was milk exposed to just vinegar, so the results of the mushroom supplements could be compared. The milk was slightly heated up, before being exposed to the various solutions for 15 minutes. After the waiting period had finished, the curdled milk was strained, measured in grams, and then recorded. The results revealed that the lion's mane and wood ear mushrooms did significantly hinder the coagulation of milk, but reishi mushrooms did not significantly impact the curdling of milk in comparison to the control. Therefore, the research hypothesis was incorrect, but two out of the three medicinal mushroom supplements did influence coagulation. It's believed that these effects are due to concentrated antioxidants in the polysaccharides of certain mushrooms. These antioxidants can inhibit the function of key enzymes in the blood clotting process. This experiment could lead to further research on the effects of medicinal mushroom supplements on platelet aggregation and potential blood thinning.

Tasker, Brooke, Central Virginia Governor's School for Science and Technology
Gut Reactions: The Role of pH in E. coli Growth

The purpose of this research project was to determine if pH affects the growth of *Escherichia coli*. *E. coli* was transferred, using aseptic technique, into a sterile nutrient broth with different pH levels at 3.5, 6.0 and 7.5. The pH of the nutrient broth was adjusted using a diluted version of hydrochloric acid or potassium hydroxide, as needed to adjust from the standard pH of 6.53. After allowing it to grow for 24 hours, a microplate reader was used to determine the growth for the 3 groups for 10 trials, with 8 samples per trial. The mean between the groups was 0.18055 for the neutral broth, 0.012025 for 3.5, 0.1764625 for 6.0, and 0.2337 for 7.5. With the data that was collected, a one-way ANOVA was run. When it showed significance, a post-hoc Tukey test was run, which showed statistical significance in the data, with a p-value of <.01, compared to the alpha value of .05. The research hypothesis, that the growth would be the highest at 7.5 followed by 6.0, with the lowest at 3.5, was supported. This experiment highly suggests that the pH has a major effect on the growth of *E. coli*, with acidic environments declining the growth of the bacteria.

Vachhani Aarna, Mills E. Godwin High School
The Effect of Chitosan on Bacterial Inhibition

The purpose of this experiment was to observe how different concentrations of chitosan affect Methicillin-Resistant *Staphylococcus aureus*, *Staphylococcus hominis,* and *Escherichia coli*. Novel compounds are needed as bacterial strains grow resistant to antibiotics. The concentrations of chitosan used were 0.00% as the negative control, 0.10%, 0.25%, 0.50%, and doxycycline as the positive control. There was a need for both a positive and negative control for the bacterial growth comparison. The research hypothesis was if 0.50% chitosan solution is used, then *S. hominis* will have the largest ring of inhibition.

All chitosan solutions were diluted using acetic acid and distilled water. Each bacteria type was smeared onto 25 agar plates. Then, six paper disks were placed equidistant around the perimeter of the agar plate, and 200 microliters of the following

solutions were piped counterclockwise: blank, 0.00% chitosan, 0.10% chitosan, 0.25% chitosan, 0.50% chitosan, and doxycycline.

The results showed that chitosan had no effect on *E. coli*, a slight effect on *S. aureus*, and a significant effect on *S. hominis*. The research hypothesis was supported because the mean inhibition radius for 0.50% chitosan was 1.66 mm, compared to MRSA with a mean inhibition radius of 0.16 mm, and *E. coli* with 0.00 mm. When a t-test was conducted *S. hominis* was statistically significant for all chitosan solutions versus the control. The 0.50% solution for MRSA was not statistically significant, despite showing an effect on the bacteria.

Microbiology & Cell Biology B (HS MCB-B)

AJAS Representative
Ertle Thompson AJAS Fellowships Memorial Endowment Award
Ann M. Hancock Microbiology and Cellular Biology Award
First Place
Gutta Ridhi, Academies of Loudoun
Combatting Lassa Fever: Investigating Pathogenesis and Constructing a Preliminary Vaccine Candidate

Lassa Fever is a hemorrhagic fever caused by Lassa virus (LASV) with an estimated >100,000 human infections per year in Western Africa. Currently, there are no approved vaccines or therapeutics against LASV. Additionally, the development process for LASV vaccines and treatments is inhibited by the necessity for high containment laboratory space and funding neglect. This research aims to characterize the first full LASV ribonucleoprotein (RNP) complex, predict potential immunogenic epitopes *in silico*, and validate those peptides *in vitro*. Here, we constructed the first full RNP complex for LASV, validating plausibility through Ramachandran analysis and molecular dynamics simulations. We also identified several T cell and B cell epitopes using advanced bioinformatic analysis. Several predicted immunogenic peptides were confirmed to be antigenic *in vitro.* Furthermore, an analysis of the sera/survival data of guinea pigs vaccinated with LASV glycoprotein DNA produced no neutralizing antibody titer, however, were protected from lethal challenge with LASV, suggesting that T-cell immunity and/or non-neutralizing antibody responses are the true drivers of successful LASV vaccination and protection. These peptides are promising candidates for future LASV vaccine construction.

Second Place
Tiwari Stuti, Mills E. Godwin High School
The Effect of Proton Pump Inhibitors on Lactobacillus acidophilus

The study was designed with the intention of revealing the consequences of consuming proton pump inhibitors daily on the gut microbiome with particular emphasis on *Lactobacillus acidophilus.* Proton pump inhibitors are a class of medications that alleviate symptoms of gastrointestinal disorders in patients. The ubiquity of the proton pump inhibitors has generated uncertainties regarding their compatibility with microorganisms residing in the body. Such questions highlight the importance of

examining the drugs' interaction with beneficial gut bacteria, like *Lactobacillus acidophilus*. One hundred *Lactobacillus acidophilus* cultures were distributed into four groups and were prepped with either Lansoprazole, Omeprazole, Famotidine, or no treatment. Cultures that received no medication acted as the control, demonstrating the bacteria's typical growth in its given medium. The cultures' turbidities were measured after exposure to estimate bacterial growth, with lower turbidity values indicating reduced proliferation. A research hypothesis formulated that if *Lactobacillus acidophilus* is exposed to 250 µL of Lansoprazole, then it will experience little to no growth in comparison to cultures exposed to other proton pump inhibitors. Results showed mean turbidity values of 2.188 for the control group, 1.829 for Famotidine, 1.356 for Omeprazole, and 0.167 for Lansoprazole, confirming the hypothesis. A t-test was performed and verified that all the results were statistically significant. The findings suggested that proton pump inhibitors overall do yield the potential to constrain bacteria growth, underlining the need for future studies to test additional proton pump inhibitors or other bacterial strains to observe the extent to which acid-reducing drugs impact the gut.

Third Place

Geunyoung Chung, Maggie L. Walker Governor's School

Environmental Rigidity and Morphological Plasticity : Modeling Cellular Adaptation to Extracellular Matrix Stiffness

Environmental rigidity alters cellular morphology and may provide a mechanobiological framework for investigating factors underlying autism spectrum disorder (ASD). While genetic research is prevalent, the physical influence of the extracellular matrix (ECM) on cellular behavioral rigidity remains under-explored. In this research, healthy fibroblasts were cultured on two substrates with distinct mechanical properties: a soft thermoplastic and rigid glass to determine if environmental stiffness induces a loss of morphological plasticity. The experimenter hypothesized that stiffer environments would cause a reduction in morphological behavior. The results proved that hypothesis true. Qualitatively, the experimenter observed that the cells attached with more ease onto the plastic substrate than the glass. In fact, Trial 2 revealed that high seeding density can override substrate-dependent mechanical cues, highlighting low-confluency as a critical parameter for isolating mechanotransducive effects. Even under high seeding density conditions, cell attachment remained consistently greater on the plastic substrate than on glass, reinforcing the influence of the substrate's role on cell adhesion. Quantitatively, cells that grew on the plastic substrate had a longer higher cell length than cells that grew in the glass substrate. These results suggest that high-stiffness environments may inhibit cytoskeletal remodeling. These findings suggest that the cellular stiffness associated with neurodevelopmental conditions may be an adaptive response to an inflexible physical microenvironment. Ultimately, this research demonstrates that mechanical cues from the ECM can fundamentally regulate cellular architecture, suggesting that the physiological rigidity observed in ASD may arise from mechanical adaptation during neurological development.

Honorable Mention

Bassam Henry, Alemy Basim, Governor's School @ Innovation Park

Combating Antimicrobial Resistance: Investigating Synergistic Effects of Antibiotics and Bacteriophages.

Background: Every year, millions of people lose their lives to antimicrobial resistance, and increasing the sole use of antibiotics has not proven to be an effective long-term solution. The primary objective of our study is to investigate whether the use of bacteriophages in combination with antibiotics could provide an effective solution to reducing antimicrobial resistance. **Methods:** To conduct our research, a K-12 strain of *Escherichia coli* was used as the bacterial host, gentamicin and neomycin were the antibiotics tested, and T2 and T4 bacteriophages were the viral agents. Luria-Bertani broth serves as a growth medium for *E. coli.* Our experiment includes three trials for each antibiotic or bacteriophage individually, as well as three trials for a mix containing all antibiotics and bacteriophages. Three control trials consisting of *E. coli,* with no biological influence. A total of 18 trials were conducted. The trials were left in a shaking incubator at 37°C and an RPM of 125 over the span of 48 hours to ensure proper growth and to allow agents to take effect. A cell counter was used to count the concentrations of bacterial colonies left in each trial. **Results:** An ANOVA test indicated a statistical difference between treatment groups, as it showed $F = 5.9$ and $p = 0.01$. This determined variation in bacterial concentrations was not due to chance, but rather the agents applied. A post-hoc Tukey's Honestly Significant Difference (HSD) test indicated how specific treatment groups differed from one another and also confirmed there was a significant statistical difference between mix treatments and the single-agent groups. The results confirmed that Phage-Antibiotic synergy is an effective treatment to combat antimicrobial resistance. **Conclusion:** Phage-Antibiotic Resistance may be a promising new treatment for individuals suffering from antimicrobial-resistant infections. Future studies should investigate where antagonistic effects between bacteriophages and antibiotics occur, and whether they can be mitigated.

Honorable Mention

Deepshika Bhoopathi, Mills E. Godwin High School

The Effect of Bisphenol A on Cell Viability

The objective of this experiment was to evaluate the effect of bisphenol A (BPA) on cell viability. Bisphenol A is a chemical compound commonly used in plastic manufacturing which can enter the body through microplastic exposure and is suspected to influence cell viability. To test the effects of BPA, human pancreatic ductal epithelial (HPDEC) cells were treated with BPA several concentrations ranging from 0μM, 10μM, 30μM, 60μM, and 120μM. Cells were incubated for nine days, after which cell viability was quantified using an MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay. Cells exposed to 0μM of BPA served as the control group. It was hypothesized that treatment with 120μM of BPA would produce the greatest decrease in cell viability. Results indicated that the 60μM group displayed the greatest change in cell viability based on the T-tests and mean, the mean exceeding the 120μM level by around 0.5. T-test values for the 10μM (8.670), 30μM (21.104), 60μM (48.220), and 120μM (45.871) versus the control were taken. All levels exceeded the critical T-table value of 2.750 indicating rejection of the null hypothesis and statistical significance. These results demonstrate that BPA significantly affects HPDEC

viability in a dose dependent manner, mainly by reducing the cell count. These findings support further investigation into the effects of BPA on pancreatic and other hormonal cells, as well as the potential health risks which may be associated with BPA exposure. Given these observed effects of BPA on HPDEC, this study aimed to explore BPA induced cell death.

Honorable Mention

Mengistu Abel, Gohil Chaitanya, Roanoke Valley Governor's School

Development of a Biocompatible DMAPS Hydrogel via Enzymatic Radical Initiation with Multi-Phase Optimizable

Biofilms contribute to persistent healthcare-associated infections mainly due to extracellular polymeric substance (EPS)-mediated diffusion restriction, phenotypic tolerance, and rapid structural regeneration following transient antimicrobial exposure. Conventional antimicrobial coatings fail to achieve sustained eradication because Fiskian diffusion generates increased-release kinetics followed by depletion below the minimum biofilm eradication concentration (MBEC). In this study, we engineered a covalently immobilized, dual-layer, dual-network zwitterionic hydrogel designed to regulate nanoscale transport of DNase I, gentamicin, and ciprofloxacin through steric mesh confinement rather than unrestricted diffusion. The scaffold was synthesized via horseradish peroxidase (HRP)/H_2O_2-mediated enzymatic radical polymerization under mild aqueous conditions to preserve enzymatic bioactivity. A sulfobetaine methacrylate (DMAPS) backbone was interpenetrated within a polyethylene glycol diacrylate (PEGDA) network and reinforced with chitosan to modulate crosslink density, swelling ratio, electrostatic tortuosity, and effective mesh size. The optimized inner-layer mesh size (~7.2 nm) approximated the hydrodynamic diameter of DNase I (~7.6 nm), inducing anomalous diffusion behavior and sustained release over 72 hours. Under dynamic low-flow nutrient conditions simulating catheter lumens, the optimized system achieved 97.29% biomass reduction in *Staphylococcus epidermidis* and 95.44% in *Pseudomonas putida* relative to untreated controls (two-way ANOVA, $p < 0.0001$). Progressive biomasses decline between 24 and 72 hours confirmed maintenance of therapeutic concentrations above MBEC thresholds. These findings demonstrate that nanoscale structural calibration governs sustained antibiofilm efficacy and establish a mechanistically grounded platform for translational device coatings.

Contractor Zayna, Mills E. Godwin High School

The Effect of Oxidative Stress on Saccharomyces cerevisiae Cell Viability

Exposure to reactive oxygen species (ROS) has been shown to alter cell survival in a concentration-dependent manner. When the amount of these ROS molecules exceeds the threshold, a cell can safely manage, oxidative stress develops, causing damage to essential cellular components such as lipids, proteins and more. The purpose of this experiment was to investigate how different concentrations of hydrogen peroxide, a reactive oxygen species, affect the viability of *Saccharomyces cerevisiae* (yeast) cells. It was hypothesized that higher concentrations of hydrogen peroxide would decrease cell survival. Yeast cell cultures were treated with four hydrogen peroxide concentrations, including a control of 0% hydrogen peroxide. These cultures were then incubated for three hours, and cell viability was assessed using methylene

blue staining. The percentage of living cells was then recorded and analyzed to evaluate the relationship between oxidative stress and cell survival. Results indicated that low levels of hydrogen peroxide stimulated cell survival compared to the control, demonstrating a hermetic effect; whereas higher concentrations caused a sharp decline in viability. Statistical analysis using a t-test confirmed that the differences in the data were statistically significant. This pattern likely occurred because low hydrogen peroxide concentrations activate protective stress-response pathways, while higher concentrations overwhelm cellular defenses and induce oxidative damage.

Daddala Darsh, Mills E. Godwin High School
The Effect of Different Types Sunscreens on Melanogenesis in N2a Cells.

This experiment investigated the effectiveness of mineral and chemical sunscreens in reducing ultraviolet (UV)-induced cellular damage associated with melanogenesis in *Mus musculus* neuroblastoma (N2a) cells. Because chemical sunscreens have been associated with potential photoreactive byproducts, determining their comparative cellular effectiveness has important implications for skin cancer prevention and public health. Chemical and mineral sunscreens were diluted to non-cytotoxic concentrations and applied to N2a cells prior to exposure to UV radiation at 254 nm. A UV-exposed sample without sunscreen served as a negative control to isolate the effects of radiation alone. Following UV exposure, cellular damage and survival were quantified using the Trypan Blue exclusion assay to measure cell viability, the DCFDA assay to measure intracellular reactive oxygen species (ROS), and the MTT assay to assess metabolic activity. It was hypothesized that chemical sunscreen would provide greater cellular protection, resulting in higher cell viability, lower fluorescence values, and higher metabolic activity. Results showed that chemical sunscreen significantly increased cell viability compared to mineral sunscreen and the control ($p < 0.05$). Although both sunscreen types reduced oxidative stress relative to the control, fluorescence differences were not statistically significant ($p > 0.05$). The MTT assay showed similar absorbance values across treatments; however, only one trial was conducted due to high reagent cost, preventing inferential statistical analysis. Overall, results suggest that chemical sunscreen provided the most effective protection against UV-induced cellular damage under these experimental conditions. These findings support further investigation using additional trials, advanced DNA damage assays, and human keratinocyte models.

Ganesh Maya, Mills E. Godwin High School
The Effect of Dog Items on Bacterial Growth

The purpose of this study was to determine how different types of dog items affect bacterial growth and to identify which commonly used item contains the most bacteria. Dogs frequently interact with bowls, beds, toys, bones, and collars, which can collect bacteria from saliva, moisture, dirt, and repeated contact. Understanding bacterial growth on these items is important because bacteria can spread throughout homes and impact pet and human health. The independent variable was the type of dog item, and the dependent variable was the number of bacterial colonies grown on nutrient agar plates. Samples were collected using sterile techniques, swabbed onto agar plates, and

incubated for one week before colonies were counted. The experiment compared naturally occurring bacteria across items rather than using a sterile control group.
It was hypothesized that soft, fabric-based items, especially dog beds, would show the highest bacterial growth. Results showed that dog beds (M = 21) and toys (M = 20) had the highest mean colony counts, while bowls (M = 5) and bones (M = 6) had the lowest. T-tests conducted at a 0.05 significance level revealed statistically significant differences between several item pairs. Overall, the results supported the hypothesis and demonstrated that porous, frequently used dog items allow more bacterial growth. These findings highlight the importance of regular cleaning to maintain a healthier home environment.

George Shaun, Mills E. Godwin High School
The Effect of Light Intensity on Arthrospira platensis Absorption

This experiment was conducted to determine which light intensity yielded the optimal biomass concentration of *Arthrospira platensis* (*Spirulina*), with biomass measured as the difference between the final and initial absorbance readings, delta absorbance (ΔA). This experiment primarily focused on low light levels and their impact on growth efficiency. Light intensity plays a significant role in cyanobacterium cultivation, as it is known to limit productivity and modulate the synthesis of proteins, pigments, and lipids, which are respectively studied for their applications in nutraceuticals, wastewater treatment, and biofuels. *Spirulina* replicates were exposed to one of five light levels (PPFD, photosynthetic photon flux density): 0 (dark photoperiod control), 35, 70, 105, and 140 μmol/m²/s, were regularly aerated, and were sampled over a 7-day incubation period. From these samples, absorbance readings at 680 nm were implemented to estimate chlorophyll content, and consequently, ΔA was determined. The light-saturation point is established at 60 μmol/m²/s. The predicted light intensity that would yield the largest ΔA was seventy μmol/m²/s, per the hypothesis. Between experimental treatments (35, 70, 105, and 140 μmol/m²/s) and the control, a t-test confirmed a significant difference between their replicates. Thirty-five μmol/m²/s, the lowest tested light level excluding the control, resulted in the largest mean ΔA of 0.313, suggesting that light saturation occurred at or below this level. Decreasing growth at the higher light intensities tested (105-140 μmol/m²/s) is consistent with the onset of photoinhibition, in which photosynthesis is impaired by photodamage, such as D1 protein damage, leading to decreased productivity.

Henry Esmarie, Mills E. Godwin High School
The Effect of Different Preservatives on Lactobacillus Growth

The purpose of this study was to determine the effect of common food preservatives on a probiotic called *Lactobacillus acidophilus*, as measured by the number of bacterial colonies that grew on an inoculated Petri dish. This is significant because of the growth in popularity of harmful food preservatives amongst large food distributors and the importance of a balanced microbiome for overall wellbeing. If it is found that a preservative is particularly harmful or comparatively healthy, it can lead to a change that will benefit everyone. The hypothesis for this experiment was that calcium propionate would allow the least amount of bacteria growth. The procedure was to put *L. acidophilus* in 10 Petri dishes and separate them into quadrants, with two Petri dishes

for each independent variable. Each trial contained a different preservative: calcium propionate, sodium benzoate, sodium chloride, potassium sorbate, and no preservative. The control was Petri dishes containing only *L. acidophilus*. The results showed that calcium propionate had the least amount of growth by a drastic amount. Yet no food preservatives showed a statistically significant impact on bacteria growth. The data collected was consistent with past research that showed that sodium benzoate along with similarly made preservatives had a negative effect on hemocyte count. Further study should use more trials, test the effects of preservatives on other vital parts of the digestive system, and use foods that already contain preservatives instead of the raw preservative to simulate a more realistic experience.

Kadiri Abhay, Mills E. Godwin High School

The Effect of Enzyme Inhibitors on Saccharomyces cerevisae Growth

Cancer is a debilitating disease caused by the unrelenting division of cells in the body. Around 1 in 6 deaths worldwide are due to malignant tumors and their respective cancers. One potential way to aid tumors and cancerous cells alike would be using enzyme inhibitors that prevent glucose reliant metabolism. This idea is still in theory, but if proven could change the world and its annual death rate. My research aims to use budding yeast or Saccharomyces cerevisiae as a eukaryotic model organism for cancer and tumorous cells. Cell proliferation and the rapid reproduction of cancerous cells are a quality seen in yeast as well. My research utilizes enzyme inhibitors to stop specific pathways and processes that would rather allow cell proliferation to occur if not managed. Yeast samples were grown with Curcumin, Quercetin, and 2-Deoxy-D-Glucose. These samples were all incubated to observe growth. Growth was observed quantitatively by measuring absorbance with a spectrophotometer at 400 nanometers. The control in this experiment was no enzyme inhibitor. A t test was performed and data for Curcumin vs. the control and Quercetin vs. the control were insignificant, while 2-Deoxy-D-Glucose vs. the control was significant. The research hypothesis was supported as 2DG yielded the most inhibitory effects on yeast. Future studies will include research on specific enzymes of yeast or cancer cells to see how they react and if Hxk2 enzymes or other enzymes are most important to glycolysis. This would help target the specific enzyme that an inhibitor would need to reach.

Lennon Lilly, Mills E. Godwin High School

The Effect of Different Caffeine Sources on Daphnia Heart Rate

This project, in its present form, is the result of different caffeine sources on Daphnia heart rate. The purpose of this research was to determine which caffeine source increases heart rate the most. Celsius, Coffee, and regular water were used with the daphnia to see the effects on their heart beats per minute. Each daphnia was placed on a depression slide underneath a microscope with either water, coffee, or Celsius. The daphnia were then observed, and their heart rate was counted for 6 seconds. The control used in this experiment was water. It was hypothesized that Daphnia observed in Celsius would produce a higher heart rate than any other variable group. The results revealed that the control produced the least bpms on average (132 bpms) than coffee (145.2), and Celsius (158.4). T-tests were conducted on the data, and it revealed that the data was significant for all experimental groups. The results did

support the research hypothesis. It is believed that the results are likely due to the independent variable levels and not from chance and error. For future continuation, this experiment will be given more time for the daphnia to acclimate, the types of caffeine will be investigated, and the daphnia will be investigated as soon as they are shipped.

Nath Sanjana, Mills E. Godwin High School
The Effect of Coagulants on Blood Coagulation

This experiment examined how different coagulants affected the coagulation behavior of synthetic blood. This information would enable healthcare providers to apply the most effective coagulant to stop blood loss and save lives. The hypothesis of the experiment was, if blood is treated with different coagulants, then electrocoagulation would show coagulation rate greater than that of other coagulants.
The independent variable was the type of coagulant used: alum, granular hemostat, and electrocoagulation. The dependent variable in this experiment was the viscosity of the synthetic blood. The control was untreated synthetic blood. The samples of synthetic blood were treated with various coagulants. At intervals of 2.5 minutes the viscosity of the samples along with the control were measured. Viscosity was measured by the time it took for the synthetic blood to flow through the viscometer. Electrocoagulation showed the highest mean viscosity (47.74 s) followed by alum (42.63 s), granular hemostat (45.67 s), and controls (33.22 s). The T-test results showed statistically significant differences between electrocoagulation and control ($p < 0.001$) and alum ($p = 0.0119$). Between electrocoagulation and granular hemostat ($p = 0.316$), the results were not statistically significant, indicating comparable effectiveness. Samples treated with coagulants showed significant coagulation. Electrocoagulation showed the most rapid coagulation and alum showed the least. Differences in the level of coagulation between electrocoagulate and granular hemostat were least, but coagulation through electrocoagulation was still higher. These results supported the hypothesis.

Wagner Katelyn, Osbourn Park High School
Observing Bacteria Growth in Prince William County Water Samples

Purpose. The design of this experiment is to test bacteria in various water samples. The six samples are bottled water, distilled water, pond water, rain water, public water fountain, and filtered well water. More than 2 billion people live in countries where their water is unsafe to drink (United Nations, 2025). One of the most common contaminants is bacteria from feces, such as *E. coli* (Washington State Department of Health, n.d.). Worldwide, about 600 million children do not have access to safe drinking water (UNICEF, 2023). In 2019, diarrhea due to inadequate sanitation caused the deaths of approximately 5.2 million children under the age of 5 (Mulatu et al., 2022).
Procedure. In this experiment, I collected six water samples, and counted the bacteria colonies grown on agar plates and Dip-Slides in a laboratory.
Observations. The control, distilled water, showed no growth. Similarly, neither did bottled water. The two samples that showed the most growth were pond water and rainwater, with pond water showing the most growth in all areas. Unexpectedly, public and well water showed growth as well. Overall, the filtration systems used to clean bottled and distilled water seem to be effective at removing bacteria.

Conclusion. While my hypothesis was correct when considering pond water, I did not anticipate the amount of bacterial growth in rain, public, or well water. This demonstrates that we need to be more aware and informed of potential contaminants in our domestic and public water supplies.

William Sleeman, Mills E. Godwin High School
The Effect of Water Filtration on Bacterial Growth

Billions of people around the world are affected by unclean water and the bacteria that live in them. The purpose of the experiment was to find the effectiveness of different water filters on bacterial growth. Discovering which water filter is the most effective at filtering out bacteria is important to the health of many around the world. Unclean water was filtered with either a Sawyer Squeeze, Iodine Tablets, Cloth Filter or not filtered. The different filtered waters were plated and incubated for 5 days and their growth was measured. The control that was used in the experiment was unfiltered water. It was hypothesized that Iodine Tablets would do the best job at reducing bacterial growth. The results revealed that water filtered with the Sawyer Squeeze had the lowest amount of bacterial growth on average, having about 10 less colonies on average than the Iodine, 100 less colonies on average than the cloth and less than several hundred on average for the control. A t-test was done, and it revealed that data was significant for all except for Filtered vs Iodine. The results did not support the research hypothesis. It is believed that the results are due to the fact that the Sawyer Squeeze has a 0.1-micron filter which is smaller than most bacteria, not letting them pass through. This research could lead to further studies that investigate which bacteria can and cannot pass through the Sawyer Squeeze filter.

Microbiology & Cell Biology C (HS MCB-C)

First Place

Davay Shiv, Thomas Jefferson High School for Science and Technology *Integrating 3D Brain Tissue Models with Molecular Dynamics to Explore Kinesin Stalling and Extracellular Vesicle Release in TBI*

Mild Traumatic Brain Injury (mTBI) accounts for over 85% of the 69 million annual neurotrauma cases yet often evades detection until 48 hours post-injury, creating an urgent need for immediate objective fluid biomarkers to assess neurological damage. This leaves millions undiagnosed, often leading to progressive neurodegeneration and long-term cognitive decline. This study aimed to identify the cellular mechanisms connecting blast forces to Rab-containing extracellular vesicle (EV) biomarker release. A 3D silk-collagen neural co-culture was engineered and exposed to blast overpressure (17-19 psi) simulating mild TBI and compared to shams (n=8 samples). Culture media were analyzed at 6- and 48-hours post-injury through Soma logic proteomics (7,000+ proteins). Simultaneously, this study modeled binding interactions (∆Delta G) between micro tubulin and kinesin via protein-protein docking to analyze axonal transport dysregulation in mTBI. Simulations revealed that mechanical deformation distorts the tubulin lattice electrostatic landscape, exposing highly polarized binding pockets indicative of a stalling mechanism. This conformational change significantly increased

kinesin-tubulin binding affinity (ΔG) from -10.5 kcal/mol (healthy) to -14.9 kcal/mol (injured), leading to excess cargo buildup. In-vitro immunofluorescence validated this stagnation and EV release, revealing distinct axonal varicosities indicative of cargo accumulation. Gene Set Enrichment Analysis (GSEA) confirmed a systemic upregulation of vesicle-mediated transport pathways and exocytosis regulation, coinciding with a downregulation of intracellular protein transport. Consequently, neurons actively ejected the stalled cargo Rab proteins into the extracellular fluid. These findings identify electrostatically driven kinesin stalling as a distinct mTBI mechanism, validating Rab-EVs as mechanistic biomarkers for axonal transport dysfunction.

Second Place

Vohra Aasiyah, Mills E. Godwin High School

The Effect of Types of Sugars on the Antimicrobial Activity of Lactobacillus Against Escherichia coli

The purpose of this experiment was to find the effects of different types of sugars on the antimicrobial activity of *Lactobacillus* against *Escherichia coli*. Recently, issues in dairy food production have occurred from the food-borne pathogen *Escherichia coli* spoiling products. Researching what sugars can support *Lactobacillus* and inhibit *E. coli* at the same time can be beneficial to the dairy industry and improve the gut microbiome. Petri dishes of *Escherichia coli* were treated with discs soaked in supernatant from liquid cultures of water, *Lactobacillus*, and sugar, either lactose, galactose, or sucrose. The zones of inhibition were measured in centimeters. The control in this experiment was no sugar, with a plain *Lactobacillus* and water solution. It was hypothesized that if galactose is used in a liquid culture of *Lactobacillus*, then the *Escherichia coli* growth will be the most inhibited. The results revealed that *E. coli* treated with the control had the highest inhibition effects on the bacteria. A t-test was performed on the data and revealed that data was significant for lactose vs. galactose and galactose vs. sucrose, but not significant for the remaining comparisons. The results did not support the research hypothesis. It is believed that the results are due to contaminants from interactions that restrict promotion of *Lactobacillus* while inhibiting *E. coli*. This research could lead to further studies that investigate the concentration of sugar to water and more saturated discs.

Third Place

Desai, Tulsi, Central Virginia Governor's School for Science and Technology

Dual-Bioremediation: The Effects of Co-Culturing Lemna minor and Pseudomonas fluorescens in Simulated Wastewater

The objective of this study was to determine whether the coexistence of a bioremediating microbe and a Phyto remediating plant results in greater pollutant removal compared to each organism alone. Four groups were prepared, each containing wastewater with the pollutants, methylene blue and sodium benzoate mixed with spring water. One of the groups served as a control with only the simulated wastewater in it. Group two contained the simulated wastewater and the bioremediating microorganism, *Pseudomonas fluorescens,* only. The third group contained the wastewater as well as the Phyto remediating plant, *Lemna minor* (duckweed). The

fourth and final group contained the wastewater and both bioremediating organisms, *P. fluorescens* and *L. minor*. Each group was sampled using a spectrophotometer at a wavelength of 650 nm. The results of the study concluded that while group four, which contained both the bacteria and the plant, did bioremediate well, group three, containing only *L. minor,* achieved greater remediation only by a minor amount. By the final day of remediation, mean absorbance was 0.0399 AU for the *L. minor* group and 0.0258 AU for the co-cultured group. A one-way ANOVA was conducted to determine statistical significance. The results of the ANOVA displayed a p-value of less than .01 and with the selected alpha value of .05, which displayed significance. Ultimately, the research hypothesis was partially supported. Although the outcome of this research did not align with the original rationale, it was nonetheless incredibly informative regarding the combination of bioremediating organisms.

Honorable Mention

Gupta Aryan, Mills E. Godwin High School

The Effect of Different Species of Cyanobacteria on Its ability to Prevent Photodegradation of Cyanotype

This project was conducted to find the UV infiltration of two different species of cyanobacteria that existed in the Archean eon to find which allows more UV to pass through. The results of this experiment were crucial because they indicate that certain oceanic regions where the cyanobacteria species existed in the Archean eon experienced evolution at a faster rate due to higher mutation rates from UV light transmission through the bacteria. Finding the UV infiltration of the bacteria can help find the origins of early complex life and where they may have arisen from. This experiment was completed by exposing 2 IV levels and a control to full-spectrum UV light to simulate UV light. The UV transmission was measured with cyanotype, a light-sensitive paper that changes color when exposed to UV. The change in RGB value of the paper before and after exposure was measured with a camera. It was hypothesized that *Nostoc Commune* would have the least difference in RGB value; the least UV light transmitted. The experiment showed that *Arthrospira Platensis* had a larger difference in RGB value and therefore allowed more light to be transmitted. *Nostoc Commune* on the other hand had the least UV light transmitted however, its statistical analysis test was insignificant with the control which means the bacteria had no significant effect differing from the control that wasn't due to chance. *Arthrospira Platensis* can be identified as a cyanobacteria species that likely incurred higher mutation rates in the Archean eon.

Honorable Mention

Nguyen Khoinguyen, Mills E. Godwin High School

The Effect of Salinity on the Formation of Coacervate Droplets

The purpose of this experiment was to determine whether salinity affects the formation of coacervate droplets. Coacervates have been gaining interest in abiogenesis research as a protocell candidate, allowing for key molecules like RNA to be encapsulated and up concentrated. Determining whether these coacervates can form in the high-salinity environments of early Earth would guide future abiogenesis research and potentially help the search for extraterrestrial life. Solutions of gelatin and

sodium alginate were mixed with different amounts of salt which reflect current and Archaean-era Ocean salinity levels (35 g/L, 52.5 g/L, and 70 g/L). A no salt solution was used as the control. The transmittance of each solution was then measured with a SpectroVis. It was hypothesized that the coacervate solution with 70 g/L of salt would have the highest transmittance. The results showed that the 70 g/L solution had the highest transmittance of all levels, thus supporting the research hypothesis. A t-test was performed on the data, and it was found that, while differences between control and salt levels were significant, the differences between salt levels were not significant. The results are believed to be caused by salt reducing the range of repulsive forces between coacervates, causing them to clump together and form solid flocs. Further research could be done on how membrane-stabilized coacervates form in these same conditions as well as evidence for possible low-salt environments on early Earth.

Honorable Mention

Stickle Tyler, Central Virginia Governor's School for Science and Technology

The Effect of Temperature on Chlorella vulgaris' Growth and Ability to Maintain Nitrogen in Water

The purpose of this research is to determine the potential effects of climate change on the ability of *Chlorella vulgaris* to absorb nitrogen in the water. The algae were kept in 300ml beakers on a BN-Link heating mat. There were 8 beakers and 4 different temperature groups increasing from 26 °C to 35 °C. Each week, for four weeks, the nitrogen (mg/L) and absorbance units (AU) were measured. Every time the nitrogen and absorbance were collected, a nitrogen substitute was introduced to maintain increased levels in the beakers. The average nitrogen level in the 26 °C group is 0.08mg/L, the 29 °C group is 0.264mg/L, the 32 °C group is 0.466mg/L, and the 35 °C group is 0.535mg/L. The average AU (Absorbance Units) in the group 26 °C is 0.0864 AU, 29 °C is 0.134 AU, 32 °C is 0.0603 AU, and 35 °C is 0.112 AU. A one-way ANOVA test was run for both absorbance and nitrogen levels respectively, resulting in a p-value of .12 and .08 with our alpha value of .05. This means there was no significant relationship between temperature and nitrogen. My research hypothesis was not supported because there was no significant difference in the nitrogen and absorbance levels among different temperature groups. These results show that temperature increases from climate change have a small effect on *Chlorella vulgaris.*

Alberti Victoria, Mills E. Godwin High School

The Effect of Fruit Content on Lactobacillus spp. Growth Using Kombucha

Probiotics are the future of Gastroenterology. These are defined as the good bacteria found in the digestive system that bring many diverse health benefits. Lately, there have been breakthroughs in digestive-health research that focused on probiotics and their health benefits. Similarly, kombucha (fermented sweet tea with a bacteria/yeast culture) has also shown similar health benefits, often with people adding fruits to flavor it. This experiment aimed to answer how to maximize probiotics in kombucha using different types of fruits to help those with digestive diseases. The different fruits were: apple, banana, grapes, and oranges. These fruits were fermented with kombucha for a week, and put into MRS agar to see a specific probiotic species found in both kombucha and fruits that is commonly sold in products: *Lactobacillus* spp.

The control is the kombucha alone without any fruit in order to show what would normally be the growth for *Lactobacillus* spp. The different groups were evaluated, and the percentage of Lactobacillus growth was measured, showing that banana was the highest growth- supporting the hypothesis. Bananas, apples, and oranges were found to be ($p<0.001$) while grapes were not ($p>0.001$) after a t-test was run. An ANOVA test was performed as well, and it showed an $\eta 2$ of .62 and shows a large effect size. The results demonstrate that different fruits are crucial to probiotic enrichment, and that kombucha alone will still give probiotics.

Holt Ann-Margaret, Central Virginia Governor's School for Science and Technology
More Than Meets the Eyelash: The Effects of Application Duration on Microbial Growth in Cosmetics

Despite daily use by billions of consumers, makeup regulations - specifically in the U.S.- remain vague, leading to inconsistencies in product testing and arbitrary expiration date recommendations. Consequently, consumers may be vulnerable to health risks, including microbial growth due to inadequate safety oversight. This research study analyzed microbial growth across a 12-week application period. One individual used separate concealer and mascara samples for 1 week, 4 weeks, and 12 weeks. The makeup samples were then used to inoculate nutrient-agar-based petri dishes. The petri dishes were incubated and analyzed to determine the mean percentages of the petri dish covered by microbial growth, as well as the mean numbers of visibly diverse colonies present across the application period. The concealer means were 61.87%, 39.25%, 12.10%, and 8.39% coverage for the 12week, 4week, 1week, and control groups, respectively. Mean species were 2.00, 1.33, 1.11, and 0.22, respectively. For Mascara, the means were 81.15%, 34.65%, 0.89%, and 0.00% for the 12-week, 4-week, 1-week, and control groups, respectively, with corresponding colony counts of 2.66, 2.11, 1.11, and 0.00. Data were analyzed using four one-way ANOVA tests followed by Tukey post-hoc comparisons. All tests yielded p-values ≤ .01 (α=.05), showing extreme significance between groups. The results of this study supported the hypothesis that prolonged makeup use increases microbial growth and colony diversity. This research supports the argument for safer makeup regulations and pre-testing to reduce potential microbial risks for consumers.

Hunt Lillian, Central Virginia Governor's School for Science and Technology
Physarum polycephalum and Their Nutrient-Driven Navigation Skills

The Purpose of this research project was to examine whether *Physarum polycephalum* slime molds will be more active when a nutrient is present and will purposely grow towards said nutrient. To do this study, there needed to be petri dishes that each contained a culture of *Physarum polycephalum* at the "start" of the path and had a designated "end". After testing 20 samples which were across four different conditions- oats with maze, oats without maze, no oats with maze, and no oats without maze- the percentage of the pathway covered from beginning to end was measured. The average percentage of the pathway covered was 83.3% when an oat was present, and 50.2% when an oat was not. A two-way ANOVA test gave a p-value of .01 when it came to a nutrient present, and a p-value of .88 when it came to the type of pathway. With an alpha value of .05 and a p-value of .01, the null hypothesis was rejected, and

the research hypothesis was supported, as the majority of the slime molds with a nutrient present were able to complete the passage and get to the nutrient. These findings suggest that *Physarum polycephalum* growth is influenced by the availability of a nutrient. This can benefit roadwork as the slime mold growth patterns can create a map to follow that shows the most direct path to each destination.

Kaplow Henry, Hampton Roads Academy
Balancing Survival: Fitness Trade-Offs Between Viral Defense and Antibiotic Resistance

Bacteriophage therapy has been used for almost a century to treat bacterial infections but was abandoned after the discovery of antibiotics. Recently, it has returned to prominence as a way to combat the global problem of bacterial resistance. Studies show that bacteriophage attacks can render the bacteria more susceptible to antibiotics than previously demonstrated. The main goal of this experiment was to measure bacterial resistance to different concentrations of the antibiotic novobiocin and the antimicrobial sodium dodecyl sulfate (SDS) in nine strains of bacteria with mutations in the TolC pump. This pump has been identified as a potential target for bacteriophage entry as well as a site of antibiotic resistance. Results showed that the bacterial strains that grew in the presence of the bacteriophage were more sensitive to both novobiocin and SDS than the wild type. These findings support the hypothesis that bacteria's survival during a bacteriophage attack results in an evolutionary fitness trade-off, rendering the bacteria more sensitive to antibiotics. Further studies in the field of phage therapy could open the door to new solutions to the current antibiotic resistance crisis.

Linford Lauren, Southwest Virginia Governor's School
Testing How Often Trombone and Baritone Mouthpieces Should Be Cleaned to Remove Streptococcus salivarius

There have been many studies related to how the different types of mold and bacteria that grow inside of musical instruments in the wind family could affect musician's health. Even though there are many reports relating to what causes these problems, there are not many studies relating to how to properly clean the instrument. One of the most commonly suggested methods for cleaning a brass instrument is to disassemble it and soak it in warm soapy water for about 15 minutes in a bathtub and the only studies that have been done that are related to this were done around the 1950s and 60s. For this project, the commonly used method of cleaning with warm soapy water was tested on a set of mouthpieces for trombones and baritones (including one positive control and one negative control). One of the more common bacteria that is found on brass instruments that comes from the body and is not harmful, known as *S. salivarius,* was used for this study. This was done by applying *S. salivarius* using a swab to three of the four mouthpieces and then placing two of those mouthpieces in their own cups that contained warm water with two drops of antibacterial Dawn dish soap. After letting them sit for 15 minutes, all four were swabbed and those swabs were then streaked onto separate petri dishes that were then incubated for about 24 hours. This was repeated four times. An ANOVA test was performed using JMP which gave means for the negative control (0 +/- 460.98), positive control (796 +/- 460.98), and the washed group (990.125 +/-325.96) along with a p-value of 0.2450. This shows that

there was no significant difference between the three groups, suggesting that the tested cleaning method did not remove a significant number of bacteria. Most of the trials had at least one mouthpiece that had more bacteria than the positive control which could have been caused by the water possibly having other bacteria in it, the fact that mouthpieces were not dried after being washed, and the drops of soap were inconsistent in size. Future research could look at different types of soap and combinations of soap. Studies could also look at whether the water is running or still or if the length of time that the mouthpiece is soaked in the water makes a difference. It could also look at if drying the mouthpiece afterwards makes a difference in colony counts.

Muse Connor, Hampton Roads Academy
Quantifying Biofilm Growth on Different Surfaces

A biofilm is a group of microbial cells that are permanently attached to a surface and are primarily covered in polysaccharide material. Clinical microbiologists have found that biofilms are associated with a wide range of infectious diseases, including cystic fibrosis and chronic prostatitis. The purpose of this experiment was to determine what surfaces allow biofilm growth or are resistant to it. Three types of beads, made of different materials (Glass, Polystyrene, and Acetate), were placed in a culture of Pseudomonas *fluorescens* overnight. These beads were stained with 0.1% crystal violet. The stain was removed, and biofilm growth was quantified using a spectrophotometer. It was hypothesized that biofilm would form more readily on glass and polystyrene beads due to their chemical properties. The capillary nature of glass enables biofilm to adhere when wet, while its ability to produce extracellular polymeric substances facilitates its attachment to the polystyrene surface. This hypothesis was incorrect, as the biofilm grew better on polystyrene and cellulose acetate beads, and less on the glass beads. This could be due to the glass bead's smooth surface and low adhesion, which prevent biofilm from sticking. Further investigation into the physical and chemical properties of the bead surfaces is necessary to understand how biofilm interacts with each type of bead.

Nair Rishi, Blacksburg High School
Comparing type 1 and 2 immunoglobulins in STAT4 myeloid cell knock out in MRL/lpr mice

Systemic Lupus Erythematosus (SLE) is a heterogeneous autoimmune disease with no known cure. Symptoms of SLE include skin rashes, arthritis, pleurisy, serositis, alopecia, and lupus nephritis which can affect one organ to an entire organ system, making it a difficult disease to diagnose. Type 1 and Type 3 immunity are known to be important factors in SLE pathology. Signal transducer and activator of transcription 4 (STAT4) is a Type 1 and Type 3 mediator, in which SNPs have been associated with lupus in human subjects. In this research, I aim to compare Type 1 and 2 immunoglobulins in MRL/lpr mice with and without a myeloid STAT4 conditional knockout (KO) to identify if it is protective in murine models. I found that there was a significantly higher IgG1 count in KO mice, signifying an upregulation of Type 2 immunity and thus cross-regulation of Types 1 and 3 immunity. Thus, the STAT4 knock out resulted in an attenuation of lupus-like symptoms in the murine model, deeming it

a possible druggable target for future therapeutics. Further research is required to determine the exact mechanism that STAT4 plays in SLE pathology, but this may provide a foundation towards new strategies to understand and manage SLE.

Pyle Logan, Mills E. Godwin High School
The Effect of Temperature on Bacteriophage Replication in E. coli

Bacteriophages are viruses that have been found to infect bacteria. They depend on the host cell's metabolic functions for replication. Many factors affect the effectiveness of bacteriophage relocation, such as temperature, by affecting bacterial growth. This study aims to investigate the effect of temperature on bacteriophage replication in *E.coli*. A nonpathogenic *E.coli* strain (K-12) and bacteriophage were used under BSL-1 conditions. A standard plaque assay method was used to quantify phage replication. *E. coli* cultures were grown and mixed with a bacteriophage suspension to allow for adsorption. The mixtures were combined with molten soft agar and overlaid onto solidified LB agar plates. Plates were incubated at four different temperatures: 25 ℃, 30 ℃, 37 ℃, and 42 ℃, for 48 hours. After incubation, plaques were counted and compared across temperature conditions. Results showed that plaque formation varied with temperature. The highest number of clearing plaques was observed at 37 ℃, while lower temperatures produced fewer plaques, and higher temperatures reduced plaque clarity. These findings suggest that bacteriophage replication is most efficient near the optimal growth temperature of *E.coli*. This study demonstrates that temperature plays a crucial role in the efficiency of bacteriophage replication. Understanding how environmental conditions influence phage-bacteria interactions contributes to broader applications in microbiology, including bacterial control, biotechnology, and phage therapy research.

Rahaman Afshin, Mills E. Godwin High School
The Effect of Various Concentrations of Croton lechleri sap on the Growth of Escherichia coli

Antibacterial resistance is a growing problem; antibiotics are becoming increasingly less effective against many bacteria, specifically *Escherichia coli*. Due to this issue, new solutions, including the usage of medicinal plants and their antimicrobial phytochemicals, are being introduced. The purpose of this experiment was to determine the effect of different concentrations of *C. lechleri* sap, a species from the genus Croton, on the growth of K-12 *E. coli*, a gram-negative bacterium. It was hypothesized that the 75% concentration of *C. lechleri* sap would have the greatest effect on the growth of K-12 *Escherichia coli* compared to the other concentrations of 0%, 25%, and 50%. The sap of *C. lechleri* was vortexed with vegetable oil to create different concentrations. This solution, through the disc diffusion method, was subjected to the bacteria in petri dishes and incubated for 48 hours. The zone of inhibition was measured to determine the results. The control for this experiment was the 0% concentration, a disc with only sterile water. The results revealed that the 50% concentration produced the largest average zone of inhibition compared to the 25% and 75% concentrations. A T-test was conducted, which revealed some comparisons to be statistically significant, while others were not. The results did not support the research hypothesis. The findings suggest

that the potency of *C. lechleri* sap is not due to its concentration level, the effectiveness of the sap may increase due to other factors, under different conditions.

Shah Ayona, Mills E. Godwin High School
The Effect of Varying Magnetic Field Strengths on E. coli Growth

Magnetic fields are becoming more popular in medical, industrial, and technological fields but their effects on our biological systems aren't completely understood. Past research suggested that magnetic fields hold a lot of influence on a lot of factors like ion movement, enzyme activity, and membrane permeability in microorganisms. This could have led to different growth patterns. This study investigated the effect of varying static magnetic field strengths on the growth of *Escherichia coli K-12.* There were four experimental groups: a control group with no magnetic field exposure (0 G) and three treatment groups with 50 G, 200 G, and 500 G magnetic fields. Each group contained 25 nutrient agar plates inoculated with *E. coli* and incubated under identical conditions for 48 hours. Bacterial growth was measured using the percent of the amount of plate covered. The t-tests, and chi-square was done at the significance level 0.01. Results showed a constant decrease in the amount of bacterial growth when the magnetic field strength got larger. The highest magnetic field group had the lowest mean percent coverage. Analysis supported rejecting the null hypothesis, which showed that magnetic field strength significantly affects *E. coli* growth. These findings showed how understanding the biological effects of magnetic fields can have many implications for health fields everywhere.

Microbiology & Cell Biology D (HS MCB-D)

First Place
Wen Kevin, Mills E. Godwin High School
The Effect of Non-Chemical, ROS-Generating Disinfection Technologies on the Airborne Inactivation of Klebsiella pneumoniae

In recent years, antimicrobial resistance (AMR) has been a leading cause of death in communal and clinical settings. With the inflation of antibiotic misuse and non-standardized biological assessments, airborne bacteria are developing into undeniable threats of the modern world, particularly those responsible for nosocomial infections like *Klebsiella pneumoniae.* Consequently, this in vitro study aims to investigate the potential of alternative non-chemical, ROS-generating disinfection modalities to effectively combat the spread of airborne *K. pneumoniae*, a predominant bacterial agent responsible for bloodstream and UTI infections in clinical settings. *K. pneumoniae* was deposited onto glass slides and placed in an isolated container where a fan blew along the surface of the slides, aerosolizing the microbial agents. The airborne *K. pneumoniae* particles then circulated the controlled environment and ran through a device named Circu25 containing a varying combination of the three proposed disinfection technologies: 222-nm far-UVC, antimicrobial blue light (aBL), and cold atmospheric plasma (CAP), after which the remaining bacteria would be collected on the glass slides for plating. The control was defined as the bacteria which received no treatment when airborne. It was hypothesized that if all disinfection technologies were incorporated,

then the antimicrobial effect would be greatest. When compared only to the control, all combinatory groups yielded statistically significant results at a level of significance of 0.001. Furthermore, the antimicrobial results were exceeding, and the hypothesis was supported, with the three-way combinatory group producing a 3.4 log10-reduction. The results are believed to be caused by applied synergistic effects in relation to photobiology.

Frances and Sydney Lewis Environmental Science Scholarship
Jo Ann B. Neely Memorial Award
VAS Honorary Membership
Second Place
Levorson Madeline, Thomas Jefferson High School for Science and Technology
Novel Antimicrobial Treatments Designed with Discovered Lytic Bacteriophages Evaluated Through a Rapid Screening Protocol and an in Vivo Galleria mellonella System

The World Health Organization estimates that by 2050, antimicrobial resistance (AMR) deaths will outnumber cancer deaths. A solution to AMR is desperately needed, and bacteriophages are a solution. Lytic bacteriophages are viruses that specifically target and kill bacteria. Lytic bacteriophages and bacteriophage cocktails have had limited treatment roles in AMR infections due to their host specificity. This research explores individual bacteriophages and phage cocktails as potential novel antibacterial treatments against *E. coli*, which is a well-known AMR threat.

To address the need for more rapid bacteriophage isolation, I evaluated four novel bacteriophages, three bacteriophage cocktails, and six novel jumbo bacteriophages for *in vitro* and *in vivo* activity against *E. coli* 11303. *In vivo* studies were performed in the invertebrate *Galleria mellonella* (giant waxworm) larvae. Additionally, I evaluated four bacteriophages for their ability to prevent biofilm formation and for antibiofilm activity using crystal violet assays. Treatment with individual bacteriophages and bacteriophage cocktails at bacteriophage multiplicity of infections (MOIs) of 10-100 significantly prevented larval mortality ($n = 92$, 1-way ANOVA, $P < 0.05$). All four bacteriophages prevented biofilm formation at an MOI of 10 ($n = 96$, 1-way ANOVA, $P < 0.05$). None of the bacteriophages eradicated established biofilms based on the crystal violet assay ($n = 96$, 1-way ANOVA, $P > 0.05$). Overall, numerous novel bacteriophages and cocktails treated *E. coli* infections in *vitro,* in the *Galleria mellonella* animal model, and prevented biofilm formation, but did not eradicate established biofilms. This research advances the field of bacteriophage therapeutics by delivering highly effective, desperately needed alternatives for treating resistant bacterial infections.

Third Place
Patel Eshaan, Mills E. Godwin High School
The Effect of Natural Compounds on Inhibition of Skin Bacteria

Antibiotics are becoming increasingly futile in the face of therapeutic resistance, prompting the researcher to explore natural alternatives. The study aimed to determine inhibitory properties of curcumin and berberine against dermal pathogens. The research hypothesis was that curcumin and berberine, when combined, will

demonstrate therapeutic synergy. Experimental conduct involved preparing bacterial solutions of *Staphylococcus(S) hominis, S. aureus,* and *Pseudomonas(P) aeruginosa* at 10^7 cells/mL and producing appropriate serial dilutions for compounds and their combination. Post-preparation, bacterial solutions were plated in a 96-well plate, and treated with dilutions of curcumin, berberine and its combination. Finally, the plate was incubated for 24 hours, and OD was measured using a spectrophotometer. The experiment included all appropriate controls (blank, negative control, positive control) to establish multiple baselines (well turbidity, non-growth, non-inhibition). The results showed that curcumin significantly inhibited all tested bacteria to a greater extent than berberine, with the latter only inhibiting *S. hominis*. The combination of curcumin and berberine also significantly inhibited all tested bacteria. Further, the combination showed strain specific synergy against *S. aureus*, indicating partial support for the research hypothesis. The conducted t-tests showed high degrees of significance, with 57 out of the 66 tests being significant. The higher efficacy of curcumin against the *Staphylococcus* strains is likely due to it being a better inhibitor of gram-positive strains, which also explains the compounds' strain specific synergy with berberine against *S. aureus.* Further research on the topic may include testing curcumin on gut microbes (helpful and pathogenic) or a curcumin and 6-gingerol combination.

Honorable Mention

Adusumilli Ritvik, Mills E. Godwin High School

The Role of Engineered Bacterial (E.coli) Biosensors as a Theranostic Treatment for Glioblastoma-Related Cancers

Amid the global health crisis of Glioblastoma (GB), which continues to claim countless lives, this study aimed to explore novel bacterial biosensing approaches to address GB, an issue largely caused by lackluster or late detection. Biosensors involving pH or Nitric Oxide (NO) detection could be utilized to combat diagnostic resistance and potentially save lives. To test this, Escherichia coli was transformed with the phluorin2 biosensor and exposed to four conditions: LB Broth with pH values of 5.5, 6.5, 8.5, and a 7.0 control. After overnight growth, the bacteria were photographed, and fluorescence was quantified in Arbitrary Units (A.U.) via ImageJ/Fiji. It was hypothesized that bacterial fluorescence would be highest at more acidic (lower) pH values. Results indicated that the pH of 6.5 yielded fluorescence exponentially greater than the 5.5 and 8.5 pH groups. Statistical analysis via t-tests confirmed significance for all comparisons except between the 5.5 and 8.5 groups. Although 5.5 pH was expected to exhibit the highest fluorescence, the 6.5 pH value, the most physiologically relevant in the GB tumor microenvironment (TME), supported the research hypothesis with statistical significance. Due to the fact that the pH value of 6.5 is arbitrarily close to GFP's emitting-portion, the chromatophore's pKa or "Goldilocks-zone," the GFP was able to glow brightest at this pH value at the 488-excitation chosen. In terms of the Nitric Oxide (NO) experiment, an NO-R sensor was utilized to detect NO concentrations, which are elevated in the GB-TME. *E. coli* was transformed with the NO-R biosensor and exposed to concentrations of 10 nM, 100 nM, 1000 nM, and 0 nM control. The NO-R sensor yielded no measurable fluorescence, suggesting potential procedural errors or sensor unsuitability for this application.

Honorable Mention

Chambers Narissa, Central Virginia Governor's School for Science and Technology
GMO Alteration Altercation: Quantitative Analysis of Concentration Based GMO Labeling Procedures

The purpose of this project is to evaluate the quantitative approach to labeling food products based on their genetically modified (GM) DNA concentration. To evaluate this, four samples of varying Bioengineered labeling statuses (two GMO (genetically modified organism) food items with GM ingredients at different weights, one non-GMO, and one Organic) were analyzed alongside three controls (positive and negative control and no template control (NTC)). I extracted DNA and amplified via qPCR to determine how GMO DNA concentration affects prospective labeling of food products. Data were collected from a qPCR standard curve, melt curve, and Cq (quantification cycle) values. Through extensive troubleshooting, abnormal standard curve efficiency (1079%), linearity (R2=0.098), and slope (-0.0933) indicated that the data could not be extrapolated to determine GMO concentration. Melt curve analysis showed the presence of bimodal peaks indicated non-specific amplification or potential false positives. Cq values were deemed anomalous due to contamination and pipetting errors and therefore were inconclusive in determining concentration without the presence of a validated standard curve. Experimental data could not be used to validate that food products heavily constituted of commonly genetically modified crops such as corn, soy, or canola contain a higher concentration of GMO DNA than food products with fewer of these ingredients. In conclusion, systematic and experimental errors precluded the quantification of GMO DNA, suggesting a need for a more robust methodology and refined calibration in future qPCR assays.

Bharti Aneesha, Mills E. Godwin High School
The Effect of Different Pollutants on Escherichia coli

The purpose of this experiment is to determine how different types of pollutants affect the growth of *Escherichia coli* as a freshwater microorganism. Pollutants such as fertilizers, motor oil, and pesticides frequently enter freshwater systems through agricultural runoff and urban waste, where they may impact microbial communities such as *E. coli*. This can make drinking water contaminated for humans and disrupt the microbial balance in the environment. *E. coli* was treated with fertilizer, motor oil, and pesticides, while distilled water was used to act as the control. *E. coli* was allowed to grow for one week and then the data on their growth patterns was recorded using a qualitative ranking system. It was hypothesized that if *E. coli* is exposed to these different environmental pollutants, then the distribution of qualitative growth ranks will differ significantly from the distilled water control. Specifically, distilled water will result in the highest growth ranks because it lacks inhibitory chemicals. The results revealed that *E. coli* treated with distilled water and pesticides displayed increased growth compared to fertilizer and motor oil. A chi-square test was done on the data, and it revealed that the data was significant ($p<0.05$) for all independent variable levels when compared to the expected data. It is believed that the results are because pesticides contain carbon or nitrogen-based compounds that the bacteria can metabolize as nutrients. This research could lead to further studies that investigate the various concentrations of contaminants applied to bacteria.

Roscoe Hughes Genetics Award

Cline Cody, Central Virginia Governor's School for Science and Technology

Cutting It Close: Finding the Minimum Cas9 Concentration for Effective Gene Editing

The purpose of this study was to determine the minimum amount of Cas9 required to successfully cut a piece of DNA in a CRISPR/Cas9 reaction. CRISPR/Cas9 is a relatively new method for gene editing. This technology has many applications, such as curing diseases and improving agricultural efficiency. This made use of Vividhabio's CRISPRCUTS Classroom Kit. The kit recommended to use .25 µL of Cas9. 7 different concentrations were tested, relative to the .25 µL: 1, 1/2, 1/4, 1/8, 1/16, 1/32, and 1/64. Each concentration was mixed with the target DNA and other reagents and then incubated at 37°C for 50 minutes. Afterwards, the samples were analyzed using gel electrophoresis. This would show if there were one or two strands of DNA, verifying if it was cut or not. Only one trial was required for each group, so no statistical test was necessary. It was hypothesized that 1/4 would be the minimum amount, but cuts happened at concentrations as low as 1/8. While I cannot statistically support my data, it gives a good indication that many experiments could be wasting Cas9. By conserving this protein, more trials could be run.

Elmekharam Ranim, Mills E. Godwin High School

The Effect of Sodium Salicylate Pre-treatment on Intracellular ROS in Yeast

The purpose of this experiment is to investigate the effect of sodium salicylate pretreatment on intracellular reactive oxygen species (ROS) levels in yeast. ROS are chemically reactive molecules that can damage DNA, proteins, and lipids, and antioxidants can reduce ROS accumulation. Sodium salicylate has been reported to have antioxidant properties, but its effect on yeast ROS has not been fully explored. Yeast cultures were grown on agar plates and incubated at 30°C for 24 hours. Following growth, yeast cells were exposed to sodium salicylate solutions at concentrations of 0 mg (control), 0.25 mg, 0.5 mg, 0.75 mg, and 1 mg in 3 mL of distilled water for three hours. After treatment, intracellular ROS levels were measured using a spectrophotometer with cuvettes, and data were recorded using Logger Pro. Each concentration was tested in 25 independent trials. Results indicate that increasing concentrations of sodium salicylate causes a decrease in intracellular ROS levels. The hypothesis, that higher sodium salicylate concentrations would reduce ROS in yeast, was supported. These findings suggest that sodium salicylate acts as an antioxidant in yeast, providing protection against oxidative stress caused by ROS. This study has implications for industrial fermentation and cellular biology research, as controlling ROS levels can improve cell survival and productivity. Further research could explore the molecular mechanisms through which sodium salicylate reduces oxidative stress.

Johnson Brandon, Central Virginia Governor's School for Science and Technology

How do different concentrations of plastic fragments in organic soil affect microbial respiration rates and nutrient

The purpose of this study was to determine whether increasing microplastic concentration in soil affects microbial oxygen consumption and nutrient availability. Three treatment groups were prepared using 200 mL of organic soil and either 0 g, 2.5

g, or 5 g of microplastic fragments. Oxygen levels were measured using Vernier O_2 sensors, and nitrogen and phosphorus concentrations were tested using LaMotte soil nutrient kits. Descriptive statistics were calculated for each group, and a one-way ANOVA was conducted to assess differences in oxygen levels. The alpha level was set at .05, and the resulting p-value was .032, indicating a statistically significant difference between groups. Post-hoc Tukey analysis showed that the 5 g microplastic group had significantly lower oxygen levels than the control. Nitrogen levels also differed significantly among treatments (ANOVA: $F(2,18) = 12$, $p < .01$); Tukey tests showed strong differences between 0 g and 2.5 g ($p = .01$) and between 0 g and 5 g ($p < .01$), but not between 2.5 g and 5 g ($p = .27$). Phosphorus showed no statistically significant differences ($p > .05$). These findings suggest that microplastic contamination may negatively affect soil respiration and nutrient dynamics over time.

Kandula Vihaan Sai, Mills E. Godwin High School

The Effect of Vitamins B1, B2, and C on Lactobacillus acidophilus

The purpose of the experiment was to investigate the effects of various vitamins on *Lactobacillus acidophilus* growth. *Lactobacillus* can be used to make many dairy products, as a probiotic, and it can even support intestinal epithelial regeneration. Vitamins are a cost-effective solution to support the growth of *Lactobacillus*. 100 plates inoculated with *Lactobacillus acidophilus* were exposed to solutions containing 1 mg/ml of each vitamin (25 each), with 25 plates containing only distilled water as the control group. A research hypothesis stating if 2 mL of a solution containing 1 mg/ml of Vitamin C is placed into a petri dish swabbed with *Lactobacillus acidophilus*, then it will show the most growth compared to the other vitamins that was formulated. Vitamin B_2 showed the greatest growth, with a median of 2 compared to the other medians of 1. However, it is important to note that Vitamin C and B_1 had a greater number of results showing growth compared to the control. A chi-square test was calculated, showing that all the results were significant, and the research hypothesis was not supported by the results. The results were likely due to B-vitamins' importance in the synthesis of various proteins, and their ability to modulate gut bacteria, such as *Lactobacillus*. Vitamin C's growth can be attributed to its ability to lower ROS, increase antioxidant activity, and increase the activity of key enzymes in glycolysis. The experiment sets up further research into the effects of different vitamins on *Lactobacillus*, and *Lactobacillus'* probiotic properties.

Nithya Vemula, Mills E. Godwin High School

The Effect of Ayurvedic Oils on the Growth of K12 E. Coli

The purpose of this experiment is to see how Ayurvedic oils impact the growth of bacteria, specifically K12 *Escherichia coli*. Ayurvedic oils are very antibacterial, and they are being used in the medical industry. K12 *E. coli* was spread over in pre poured agar dishes. A sensitivity disk dipped in an Ayurvedic oil was placed in the designated section of the plate. It was allowed to grow for 120 hours, and the zones of inhibition were measured. The control used was no oil, as its absence provides a baseline for comparison. It was hypothesized that turmeric oil would promote the least growth of K12 *E. coli*. The results revealed that Ayurvedic oils do affect the growth of K12 *E. coli* and that Eucalyptus oil had the least growth because it had the largest zone of inhibition

among all the others. A t-test was done on the results, and it revealed that all the data was significant except Turmeric oil vs. Eucalyptus oil. The results did not support the research hypothesis. It is believed that the results are due to the antibacterial properties (properties that make them fight bacteria) each oil has, and what they have that makes them more antibacterial. That is why K12 *E. coli* treated with Eucalyptus oil had the least growth, because it was more antibacterial. This experiment could lead to further experiments, such as how Ayurvedic oils affect fungi or how different bacteria are affected by Turmeric oil.

Riya Nimonkar, Mills E. Godwin High School
The Effect of TMS Device Amplitude on The Change in Number of Lactobacillus Cells from Yogurt

The purpose of this experiment was to find the effect of different amplitudes from a TMS device on the number of *lactobacillus* cells. TMS devices are used to alter neurons and the same can be done with probiotics to decrease fermentation time. Well plates of yogurt dilution were subjected to either 0% (0.0T), 25% (0.25T), 50% (0.5T), or 75% (0.75T) amplitude, with 0% as the control. After subjection, the pre- and post-images taken from a light microscope were compared in ImageJ to find the difference in cells after growth, though the data for 25% and 75% were not collected due to the TMS machine breaking from an external source. It was hypothesized that 75% would induce the most growth. The results revealed that 50% had a more drastic and positive change in number of cells than 0%. After conducting a t-test, it was revealed that 0% vs. 50% was statistically significant, though it cannot be confirmed if the hypothesis was supported due to the data not being collected. It is believed that the results are due to AC magnetic fields (AMFs) inducing sped up lactic acid fermentation which increases the number of *lactobacillus* cells when subjecting the wells to 50% amplitude. This research could lead to further studies that explore which specific amplitude and frequency induce the most probiotic growth in subjects.

Sahasra Sudeep, Mills E. Godwin High School
The Effect of Different Acne Vulgaris Medications on Escherichia coli.

The purpose of this experiment was to examine the effects of acne vulgaris medications on Escherichia coli, specifically to determine which ones are the most effective. Acne medications are widely used by individuals who want to manage acne, however their true effectiveness against acne causing bacteria is not always clear. In this experiment, E. coli was exposed to commonly used acne treatments, benzoyl peroxide, salicylic acid, and retinol, and sterile water served as the control. After a forty eight hour incubation period, zones of inhibition were measured to assess and compare each medication's antibacterial action. It was hypothesized that if E. coli is exposed to different acne medications, then the size of the inhibition zones will differ significantly from the sterile water control. Specifically, that if Benzoyl peroxide is used, then it would result in the highest zone of inhibition in the Petri dishes containing E. coli. The results showed that E. coli treated with benzoyl peroxide and salicylic acid exhibited larger zones of inhibition compared to retinol and the water control. A t-test was conducted on the data, and it showed that the differences between all medication groups and the control were statistically significant ($p < 0.05$). These results are likely due to the strong

antibacterial properties of benzoyl peroxide, salicylic acid, and retinol which all effectively inhibit E. coli growth compared to water. This research suggests opportunities for future studies to explore the effects of different concentrations and formulations of acne medications on bacterial inhibition.

Stewart Matthew, Clover Hill High School
The Effect of Feeding Various Types of Algae (Green, Brown, Red) to Tardigrades on the Reproductive Rate of Tardigrades

The purpose of this experiment was to determine which type of algae (green, red, brown) would have the greatest reduction in water bear reproduction. Normally, a water bear's diet consists of purely green algae, which is biochemically similar to red algae but different from brown algae. Water bears can fully develop and lay their eggs within two weeks of being fertilized. When water bears reproduce while consuming a new kind of algae, their reproductive rate does not change. One of the most resilient creatures in the world cannot be stopped by a change in diet. The original hypothesis stated: If green, red, and brown algae were fed to water bears, the red and brown algae will decrease the water bear's reproductive rate. After the water bears were in place for three days, they were evaluated for the following 6 weeks. The procedure consisted of evaluating each petri dish once every three days to count any eggs that had developed within a water bear or had been laid in the dish. After being counted, the change in reproductive rate was calculated by evaluating the current day's number of egg sacs and subtracting that total from the number of egg sacs three days ago. The mean reproductive rate of the green algae consumers was 4. The mean reproductive rate of the red algae consuming water bears was 4. The mean reproductive rate of the brown algae consuming water bears was 4. The different types of algae did not have an effect on the water bears' reproductive at the end of the experiment; however, the reproductive rate of the red and brown algae was significantly hindered by the algae available to them. By week two of the experiment, or the normal gestation time of water bears, the green algae had an average of 2, the red algae had an average or 1 and the brown algae had an average of 0. The reproductive rates based on different algae consumptions will not change over a long period of time, but over a short period of time the reproductive rates hindered greatly by the change in food.

Varshini Jagarlamudi, Mills E. Godwin High School
The Effect of Natural Extracts on Bacterial Growth

The purpose of this experiment was to determine which natural extract is the most effective in preventing bacterial growth. As antibiotic resistance becomes an increasing problem due to overprescription, researchers are turning towards natural, cost-effective alternatives to improve healthcare and reduce reliance on common medicines. It was hypothesized that using garlic extract would result in the largest inhibition zone because of its bioactive compounds. The experiment was conducted using an 80% concentrated solution of each extract and was tested using a well diffusion method on agar plates inoculated with *Escherichia coli K-12.* Distilled water was used as a control group, allowing for comparison against the collected data. The agar plates were incubated at 37°C for 24 hours. At the end, the zones of inhibition were measured in millimeters. The results showed that garlic was most effective with a

mean of 15 mm, followed by honey at 12 mm, while ginger was ineffective. A t-test confirmed that the garlic and honey data were statistically significant, supporting the research hypothesis. However, the data was not significant for ginger vs. control. It is believed these results occur because garlic's allicin directly attacks bacterial enzymes, while honey uses bee defensin-1 and osmotic pressure to dehydrate and destroy the bacterial cells. Moreover, ginger was likely ineffective since it requires a higher concentration to perform optimally.

Physics & Astronomy A (HS PHY-A)

First Place

Tkabladze Luka, Yorktown High School

The Effect of Applied Force on the Voltage Measured across a Beam of Ice

Background: Ice has long been considered electrically inactive under normal conditions. Its crystal structure, governed by the Bernal-Fowler rules, also known as the ice rules, produces no net spontaneous polarization, and unlike quartz or other piezoelectric materials, ice should not produce a voltage when uniformly squeezed. That assumption changed in 2025, when researchers published a foundational study in *Nature Physics* reporting that ordinary hexagonal ice (ice I_h) can generate measurable electrical signals, not from uniform pressure, but from bending. The mechanism responsible for this effect in ice is flexoelectricity, which is electrical polarization caused by a strain gradient, the variation in deformation (for example, when one side of a material is compressed while the other is stretched). The purpose of the present study is to answer the question: How does increasing applied load in a three-point bending setup affect the voltage measured across a beam of pure ice? **Methods**: Uniform rectangular ice beams were prepared in identical molds using distilled water. Aluminum foil strips, acting as electrodes, were frozen to the top and bottom surfaces of each ice beam and connected to a Vernier voltage probe with Vernier LabQuest Mini. Each beam was placed on a two-point wooden support stand built for this experiment. Loads of 0g (control), 100g, 200g, 300g, and 400g were applied by hanging the weights at the midpoint to create a three-point bending force with 8 trials for each level. **Results**: The mean voltage measured consistently increased with load: 0.853V (0g), 1.042V (100g), 1.211V (200g), 1.328V (300g), and 1.481V (400g). A T-Test and ANOVA test both resulted in p-values less than 0.05, indicating a statistically significant effect of applied load on measured voltage. Linear regression of voltage on load showed $R^2 = 0.993$, indicating a strong positive correlation. The hypothesis was supported. A greater applied load produced greater measured voltage across the ice beams, because larger bending generates larger strain gradients and flexoelectric theory predicts that polarization increases with the magnitude of strain gradient. This is consistent with flexoelectric theory and recent peer-reviewed sources. **Conclusions**: These results demonstrate that a load-dependent electrical response of ice can be measured and quantified using student-accessible equipment, and that voltage output scales predictably with applied load. Future work should explore saline ice compositions, different electrode setups, and longer time measurements to further study the electromechanical behavior of ice and contribute to its significant potential applications

in atmospheric science, cold-environment technology, and studies of icy planetary bodies.

Second Place

Massat Benaich Lillian, Biggins Norah, Osbourn Park High School

An Experimental Analysis of the Drag Reduction System Using Computational Fluid Dynamics

The Drag Reduction System (DRS) is a flap that can be opened or closed on the rear wing of racecars to gain a speed advantage. It opens to increase top speed while reducing drag, a slowing force. The purpose of this project was to develop a more effective DRS by determining the best angle of attack for the flap to produce the most lift while decreasing drag. The hypothesis stated that an angle of attack of 10°-15° would provide the highest Lift-to-Drag ratio. This was based on research that showed increasing the angle of attack reduces drag. The data collected and the results found in this experiment can be used to inform racing teams when designing cars, giving them better aerodynamics and an advantage during races. The data was collected using the ANSYS R2 2025 computational fluid dynamics software to provide accurate results. A 2D model of a rear-wing airfoil was created and meshed into the simulator. Tests were performed for each angle of attack (-5°,0°,5°,10°,12°,15°,20°) and values for the coefficients of drag and downforce (negative lift) were calculated. The simulation was set to run 1000 iterations for each angle of attack in order to provide a large data set to increase accuracy of the results. The experiment found that an angle of 20° provided the highest Lift-to-Drag ratio. This experiment successfully evaluated the effect of angle of attack on the resulting drag and downforce, which will contribute to the design of racecar technology in the future.

Third Place

Kungu Chanelle, Central Virginia Governor's School for Science and Technology

The Influence of Anthropogenic Light Pollution on Star Visibility and Night Sky Brightness

To explore the influence of light pollution on the night sky, two locations were chosen, one inside and one outside of a city's light dome. Night sky brightness (NSB) measurements were taken with a Sky Quality Meter - L and stars of differing brightness were counted if visible, over four nights in December 2025 and January 2026. For Location 1, the NSB mean was 18.93 mag/arcsec^2; Location 2, the mean was 19.84 mag/arcsec^2. The visible faint star data showed a decreasing count as dimmer stars were sought, and Location 1 had less visible faint stars than Location 2. The Multi-Factor ANOVA was conducted for the NSB data (alpha = .05; location p-value = <.01, night p-value = <.01, interaction p-value = <.01). For visible faint star data, the Chi-Square Test for Independence was run (alpha = .05; p-value = .63). The research hypothesis was partially supported, which was that if the average brightness of the night sky over a location within the light dome of a certain city as compared to one outside is within the range of magnitude per square arcsecond (mag/arcsec^2) values that are ranked as a V or higher on the Bortle scale, then stars of magnitude 4 and higher in and near select constellations will be more difficult to perceive there than at the location outside of the light dome. The outcomes of this study will contribute to observational

astronomy by giving basic and foundational context to the impacts on the night by light pollution.

Honorable Mention

Paine Charlotte, Clover Hill High School

The Effect of Various Combinations of Springs on a Gymnastics Springboard on Maximum Height Attainable Off the Board

Gymnastics carries a high risk due to repetitive, high impact landings. The efficiency of the springboard is crucial in converting the gymnast's run-up kinetic energy into vertical potential energy. This experiment investigated how different combinations of springs in the springboard affected the vertical height obtainable off the board. It was hypothesized that 5 springs would produce the most height with a 4.5 kg medicine ball by offering a preferable balance between stiffness and compression. The medicine ball was dropped from a constant height of 1.23 onto a springboard with 4, 5, 6, and 7 springs. A control group involved dropping the ball directly onto the floor. The rebound height was recorded using a slow-motion camera. The results concluded that the 4-spring combination produced the highest mean rebound height (39.13 cm). As the number of springs increased, the mean height generally decreased. An ANOVA test yielded a P-value of approximately 0, rejecting the null hypothesis. It is concluded that while more springs increase stability, a lower spring count is necessary to allow compression of the board with lighter objects.

Yoder Gibson, Central Virginia Governor's School for Science and Technology

A Comparative Study of Traction Sprays and Their Impact on Basketball Shoe Friction

The purpose of this study was to determine whether popular commercially available grip-enhancing sprays increase the outsole traction of basketball shoes. Three popular grip sprays (Performance Grips, Grip Spritz, and Cuts Traction) were applied to the outsole of a basketball shoe and compared to a control shoe with no spray applied. Static frictional force was measured on a polyurethane-coated maple surface to quantify traction. A one-way analysis of variance (ANOVA) was used to analyze differences in grip strength among the four groups. Descriptive statistics showed that all grip spray conditions produced greater static frictional force than the control, with Performance Grips producing the highest force of static friction (approximately 40 N). The ANOVA revealed statistically significant differences between groups, with a p-value of $< .01$ and an alpha level set at 0.05. Post-hoc Tukey test was used and showed that each grip spray group demonstrated significantly higher traction than the control group. These results supported the research hypothesis that the application of grip-enhancing sprays would improve outsole traction compared to no spray application. In conclusion, the findings suggest that grip-enhancing sprays can effectively increase static friction and traction on indoor basketball surfaces, potentially improving athletic performance and reducing slipping-related injuries.

Popel Polina, Mills E. Godwin High School

The Effect of Vibration Dampeners on Distance of Tennis Balls

The purpose of this experiment was to investigate how different vibration dampener materials influence the distance traveled by a tennis ball after racket impact,

with the goal of determining whether certain materials preserve more rebound energy than others. The study examined rubber, silicone, and plastic dampeners, based on the hypothesis that rubber would produce the greatest ball distance. This research has practical applications for tennis players, coaches, and equipment manufacturers seeking to optimize performance. The experiment was conducted on an indoor tennis court using a ball machine that launched balls at a constant speed toward a racket secured in a fixed holding device. The control used in the experiment was a racket with no vibration dampener. Each dampener type was tested across 25 trials, and the distance from the racket to the ball's landing point was measured. The results showed that the rubber dampener produced the greatest mean distance, while the plastic dampener produced the shortest, and the silicone dampener performed similarly to the control. Independent two-sample t-tests were performed, and they revealed statistically significant differences for all comparisons except the silicone dampener versus the control. These findings indicate that vibration dampener material can significantly affect ball distance because materials differ in stiffness and vibration-absorption properties that influence energy transfer. This investigation may be extended to examine additional performance variables such as vibration amplitude, spin rate, and player comfort.

Physics & Astronomy B (HS PHY-B)

Jones/Ellett Award
Physics and Astronomy Award
First Place
Leguto Joe, Collegiate
The Effect of Satellite Trails on Signal to Noise Ratios for Astrophotography

As the number of satellites increases in Earth's orbit, determining the effect of these satellites on Astro photographic data quality is important. Using a hobbyist astrograph, photographing four different deep space objects, the effect of satellite trails appearing in one 60 second individual exposure (a "sub") of a given stacking set on the resultant stacked image's signal-to-noise ratio (SNR) was analyzed. By stacking ten subs with no apparent satellite trails, a control frame was established. By stacking nine of the ten same subs, a no trail frame was created. By adding a contaminated sub with a satellite trail to the nine subs, a trail frame was produced. The subsequent SNRs for these frames were analyzed by calculating the percent difference in SNR between the control and trail frames, and the no trail and trail frames. From here, the percent differences of both the control vs. trail, and no trail vs. trail of every pair of deep space objects were compared, and a paired sample t-test was run to determine the significance of these relationships, where p is significant at < 0.05. For the SNR percent differences of the control vs. trail frames, four of the six pairs between the four deep space objects were found to be significant, whilst only two of the six pairs between the four deep space objects for the SNR percent differences of the no trail vs. trail frames were found to be significantly different. What these findings suggest are two-fold: firstly, that satellite trails have a somewhat significant effect when included in a stacking set versus an ideal stacking set without satellite contamination, and this effect seems

dependent on the deep space object being imaged; and secondly, that the no trail frame is more similar to the trail frame in SNR than the control frame is to the trail frame. Thus, according to the limitations of this study, the scientific community should take steps to address the problem of satellite contamination in astrophotography, as the problem of scientific reliability will only worsen with more satellites and more advanced equipment.

Second Place

Allauddin Taha, Collegiate

How Different Roughness Levels of Cricket Balls Affect Their Movement in the Air

In the sport of cricket, a bowler throws the ball to a batter with a desire to make the batter's job of hitting the ball difficult. Bowlers commonly use swing for this task. Swing causes the ball to move laterally while in flight, thus changing the location from which the ball approaches the batter. As the ball moves in the air, batters have little time to read the ball and react, creating more difficulty in selecting a proper shot when there's side-to-side deviations. As the game of cricket progresses, the ball gets rougher as it makes contact with different surfaces. The roughness then adds to the amount of swing the bowler can get. This experiment examines how varied roughness levels of cricket balls altered the amount of swing generated for each. Three different balls were rubbed with the same grit of sandpaper for different amounts of time to create the different roughness levels: very rough, moderately rough, and slightly rough. A pitching machine launched the balls, and the amounts of swing were analyzed. The very rough ball had the most swing (1.59 ± 0.17 horizontal meters from control), followed by the slightly rough (0.71 ± 0.11 horizontal meters from control). The slightly rough ball had the least amount of swing (0.61 ± 0.14 horizontal meters from control) (ANOVA, df = 21, p = 0.0004). As a cricket game goes on and the ball gets rougher, players can expect the ball to have significantly more swing and adapt their strategy to this belief.

Third Place

Walker Ella, Central Virginia Governor's School for Science and Technology

The Effects of Hydrophobic Coatings on Monocrystalline versus Polycrystalline Photovoltaic Cells Under Identical Conditions

The purpose of this experiment was to investigate the effects of hydrophobic surface coatings on the energy production of monocrystalline and polycrystalline photovoltaic cells energy production. The experiment consisted of six solar panels, three monocrystalline and three polycrystalline, and within each cell type, one panel was coated with "solar wash" and the other with a "nano coating" leaving one panel uncoated to serve as a control. Energy output data was then analyzed using a Two-Way ANOVA test, with an alpha value at .05. The results yielded a p-value of .5 representing coating type, <.01 representing cell type, and .97 representing the interaction between variables. Furthermore, a post-hoc Tukey test was run to confirm that there was a statistical significance difference between types of photovoltaic cells. When looking at the different types of hydrophobic coatings in comparison to the control, the results showed little evidence that the coatings significantly increased energy efficiency. However, no coated panels exhibited a decreased performance in comparison to the controls, suggesting they met performance expectations as no data points were negatively impacted in energy production. Overall, the results partially

supported the research hypothesis, which was that if a monocrystalline and polycrystalline solar panel were coated with a hydrophobic coating then, the monocrystalline panel will show a greater production in energy compared to the polycrystalline panel. The findings indicate that monocrystalline photovoltaic cells exhibited higher energy output when compared to the polycrystalline photovoltaic cells, regardless of coating application.

Honorable Mention

Lamb Charles, Central Virginia Governor's School for Science and Technology

Influence of Internal Bow Angle on Vertical Profile of Boat Wakes Under Varying Propulsive Forces

The purpose of this study was to determine how the internal bow angle of a boat's hull under varying forces affected the wakes produced by the displacement through the water. This study was conducted at a local high school in December 2025. There were three internal bow angles used: 60, 90, and 120 degrees. Each of the hulls was 3D printed to meet its specific designs. There were three forces used on the different hulls of 0.5886 N, 0.7848 N, and 0.981 N. The hull designs were placed into a trough and were propelled using the force groups. At a point half a meter from the tip of the hull's starting point, cameras recorded the size of the wakes produced by the displacement of the hulls. A Two-Way ANOVA test revealed P-values of less than .01 compared to the alpha value of .05. This resulted in a Tukey Test that yielded significant results in 33 out of 36 possible hull force interactions. The changes in the wake size values and the statistically significant data supported the research hypothesis; as the internal angle of the bow of a vessel decreases, it will have a reduced wake produced, regardless of how much force is propelling it at that set distance. The results suggested that as the internal bow angle increased, the wake size produced would be greater than the wakes produced from a small, angled hull under the same force.

Honorable Mention

Baron Michael, Southwest Virginia Governor's School

The Effects of Assorted Fluids on Saxophone Reed Durability

The saxophone is classified as a woodwind instrument, so it requires a reed to play. However, these reeds must be in fresh condition for sufficient sound quality, and they unfortunately stay fresh for a short period of time. The wood weakens quickly since it is salivated in the mouth each time before playing. Reeds must be wet, as the process decreases their sensitivity to air and vibration. Research on reed preservation is crucial, since cane plant is limited, weak, and rare. This makes reeds expensive to make, raising their sale price. Anything to make this tool last longer highly benefits players both financially and regarding the sound quality associated with a reed in optimal condition. Thus, the question arose, *can reeds be lubricated with a method that weakens them less?* Because reeds are soft and flexible, they can be bent to test properties. In this case, shear modulus was tested as a measure of rigidity. Using water, saltwater, baking soda aqueous solution, and vegetable oil, reeds were soaked for an equal amount of time. They were subsequently bent with light force to calculate shear modulus. A statistically significant difference was found between the average rigidity of two reed groups: the vegetable oil group versus reeds under the traditional method.

This discovery provides a foundation for future research in sound quality for saxophones, given reeds can last longer when soaked in vegetable oil.

Honorable Mention

Shiju Ryaan, Mills E. Godwin High School

The Effect of Spin Type on Soccer Ball Float Time

The purpose of this experiment was to determine how different types of spin affect the float time of a soccer ball. Spin is a factor in soccer because of how long the ball remains in the air and how it moves. Understanding how spin affects float time can help players improve performance and make better decisions. The independent variable is the type of spin applied to the soccer ball, including curve (sidespin), backspin, power shot, and chip shot. The dependent variable is the soccer ball's float time, in seconds. No control group was used in this experiment because a no-spin kick would require advanced skill and would create large numbers of outliers in the data. The experiment was conducted on a flat outdoor field using a standard size-5 soccer ball. 25 trials were completed for each type of spin, a total of 100 trials. Float time was measured using video analysis by recording the time from when the ball left the ground to contacting the ground again. The data was analyzed using descriptive statistics and t-test at a level of significance of 0.05 with 48 degrees of freedom. The results showed that the chip shot had the greatest average float time, then backspin, curve, and power shot. Statistical analysis showed that the differences between the types of spin were significant, showing that spin had a measurable effect on float time. Overall, the data supported the research hypothesis. This experiment shows how spin changes motions of a soccer ball and the importance of aerodynamic forces.

Thompson Ania, Central Virginia Governor's School for Science and Technology

Exploring Early Planet Formation: Dust Grain Growth in Orion Class 0/I Disks with ALMA and VLA

Although we know that planets form in protoplanetary disks, we still do not know when planets begin to form in these disks. This study examined the dust grain size in five very young protoplanetary (Class 0/I) disks in the Orion molecular cloud. Continuum fluxes at 345 GHz and 33 GHz, taken with ALMA and VLA telescopes, were used to measure the spectral index; this gives an idea about the dust grain size in these disks. Dust grains are expected to be small in these very young disks, but these results suggest the presence of large dust grains in these disks. These results are interesting because it could point to the limitations of certain methods used for analysis, or it could also suggest the current understanding of planet formation is incomplete. The data was also compared using a spectral index method to a more advanced and computationally expensive method to estimate dust grain size. Based on the information from a paired T- test, the null hypothesis was rejected; with a P-value of .02, it is below the alpha value of .05. This test further shows that this approach compared to the paper is significantly different. In conclusion, this work conveys the need for careful modeling of the disks including observations at different frequencies and contributes to the field of planet formation by researching the question of when planets begin to form in the protoplanetary disks.

Psychology A (HS PSY-A)

First Place

Fernandez Alejandra, Central Virginia Governor's School for Science and Technology

More Than Just Words: How Connotation Affects Emotion and Trust

The purpose of this research was to study whether there is a relationship between writing connotation, emotional response, and trust level. To do this, participants were recruited from local high schools, and each was given a short informational piece with six scale-based questions on feelings after reading, along with one scale-based question on trust in the information presented. There were two different writing topics for variation, each with one written in neutral connotation, one in positive connotation, and one in negative connotation. After the 36 participants completed their surveys, an ANOVA test was run on the different scores between neutral, positive, and negative connotations. The resulting p-values were .01 and less than<.01 (α=.05), meaning the data was statistically significant, so a post-hoc test was run. The post-hoc test showed that the emotion scores were significantly different for each category. Another ANOVA test was run for the trust scores, but the p-value was .73 which is not significant. These results suggested that the research hypothesis, "If language connotation of an informational piece is positive, then predominant emotional response will be positive and trust of content will be greater compared to if the informational piece was negatively connotated, emotional response would be negative and trust level of the content would decrease," was partially supported. This experiment showed how easily audiences' feelings and opinions can be changed through language connotation.

Second Place

Mistretta Jack, Central Virginia Governor's School for Science and Technology

The Effect of Color Exposure on Mood, Heart Rate, and Blood Pressure

The purpose of this research was to explore how an individual's mental and physiological reactions are impacted by color exposure to further understand the connection between mind and body. This study was conducted over a period of three weeks, using 14 local high school students. Each student took a SPANE - 12 mood survey and a blood pressure/heart rate measurement before entering the red, blue, and white lighted rooms, and again and after leaving them. The difference between these values was measured and analyzed to determine significance. The researcher determined there was no significant change in heart rate and blood pressure after each color exposure. However, there was a relationship between mood and room color. After leaving the red room the participants' mood score decreased significantly, while after leaving the blue room it increased significantly. To determine significance, a single-factor ANOVA was run with an alpha value of .05 and p-value of < .01. A post hoc Tukey test returned a p-value of .02 when red was compared to white and a p-value of <.01 when red was compared to blue. The research hypothesis that predicted exposure to the color red would have a negative effect on blood pressure, heart rate, and mood, while blue would have a positive effect was partially supported by the data. This study demonstrated that short term exposure to color can significantly influence mood, which

should be taken into consideration when designing spaces like schools, stores, and hospitals and when treating certain mood disorders.

Third Place

Sheth Dhanvi, Deep Creek High School

Prevalence of Trait and State Anxiety in High School Athletes

Introduction:

Sports competitive anxiety impairs athletic performance and serves as a psychological barrier to athletic recovery. Besides somatic and cognitive variation, competitive anxiety can also be differentiated by its state or trait quality. There is a significant lack of studies on anxiety rates in young adult athletes in high school settings, especially when measuring two types of anxiety.

Methods:

The study is a case-control design conducted at Deep Creek High School. The study protocol was approved by local IRB. The Sport Anxiety Scale-2 (SAS-2) and Competitive State Anxiety Inventory-2 Revised (CSAI-2R) questionnaires were administered to members of the school's swimming team (cases) and non-athlete students from the same school (controls).

Results:

A total of 15 swimmers (cases) and 6 non-athlete students (controls) completed the (SAS-2) and the (CSAI-2R) questionnaires. Swimmers demonstrated significantly higher overall SAS-2 and CSAI-2R scores compared to controls (SAS2: 32.2 ± 9.46 vs. 21.5 ± 5.68, $p = 0.02$) (CSAI-2R: 37.27 ± 5.83 vs. 24.83 ± 2.56, $p = 0.0001$). Both trait and state anxiety were elevated in swimmers as compared to controls.

Conclusion:

The findings of this study support the presence of competitive trait and state anxiety among high school athletes, including higher somatic and cognitive anxiety. The study is limited due to its cross-sectional design, limited sample size and self-reporting questionnaires. However, understanding the prevalence of sports anxiety in high school athletes as well as distinctions between trait and state anxiety is essential for developing targeted interventions that promote both athletic performance and psychological well-being.

Honorable Mention

Pendlebury Eric, St. Christopher's School

The Effect of Background Music on Male Performance on Math Assessments in High School Math Classes

Selective attention, the ability to maintain focus on relevant stimuli while suppressing distracting information, is a key component of academic achievement. However, the regions of the brain associated with selective attention continue in their development throughout adolescence. Based on existing evidence, which suggests that music activates neural networks associated with attention, memory, and executive function, this study sought to determine the effectiveness of background music as an academic tool for male students in high school math classes. The study gathered data from ten high school math classes from sections of Algebra II, Precalculus, and Precalculus Honors at Saint Christopher's School in Richmond, Virginia. These

classes, each containing roughly 12 students, completed four SAT-style math assessments over a 21-day period; two without background music, and two with background music based on general class preferences. Individual student scores within each class level were compared using one-sided paired t-tests (α = 0.01). Results indicated statistically significant improvement for individuals in the Algebra II level (p-value =1.68 x 10^{-5}). However, no significant impact was found for students in the levels of Precalculus (p-value = 0.0744) and Precalculus Honors (p-value = 0.22). These results suggest that background music may be more beneficial for younger students, potentially due to developmental differences in neural regions associated with selective attention. While background music may be an effective, low-cost academic tool for younger students, its impact may not be consistent across age groups. Further research, with a larger sample size and possible changes in experiment design, is required to clarify the scope of music's potential as an academic tool.

Nock Mia, Mills E. Godwin High School

The Effect of Prior Stimulus on Emotion Recognition Accuracy

This study was conducted to determine the effects of Prior Stimuli on human ability to recognize emotions. To conduct this experiment, 25 volunteers completed four experimental sessions, each testing a different stimulus targeted to impact the participants' emotion recognition ability in some way. In each trial, participants received one of the prior stimuli for three minutes; either listening to New York City Traffic sounds, box breathing, listening to a short story and completing an emotion connection activity, or the control of absence of stimuli. This control was included to determine each participant's baseline ability to recognize emotions, allowing any changes in this ability to be observed. A statistical analysis revealed that the levels of box breathing and short story with emotion connection activity were significant vs. the control ($p < 0.01$). On the other hand, the level of New York City traffic sounds was not proven significant when compared to the control ($p > 0.01$). The greatest mean improvement in emotion recognition was 87.2% accuracy for box breathing, compared to the mean of 70.4% accuracy in the control group, supporting the hypothesis that box breathing would result in the greatest accuracy of emotion recognition. Prior research suggests this improvement is made possible because box breathing helps to reduce stress and regulate the nervous system, promoting a physiological state conducive to accurate emotion recognition. This research is valuable to anyone working to improve emotional awareness, enhance communication, relationships, and social situational understanding.

Baber Isaac, Central Virginia Governor's School for Science and Technology

The Relationship Between Student Importance of Geography and Geography Test Scores

The purpose of this study was to examine the relationship between how high school students perceive the importance of geography and their resulting geography test scores. The hypothesis was that if students perceive geography as important on a higher level, then they will score higher on a geography knowledge test. A total of 33 local high school students, between the grades 9-12 were given a survey and test via email and were asked to complete each without outside assistance. The scores of the

participants were used in calculating the averages for the survey and test: 34.18 out of 50 and 17.52 out of 30. Furthermore, the scores of all the participants were run through a correlational and linear regression test, resulting in a statistically significant P-value (<.01) when compared to the alpha value (.05). Also, the resulting data from the correlation test gave an r-value of .62, which represents a strong positive correlation between the Importance Levels and Test Scores. With both of these values, there was significant evidence supporting the research hypothesis. In conclusion, the importance of geography perceived by students affected the test score gained. Moreover, this displays the importance of teaching geography as students will retain that knowledge and therefore apply it to everyday life.

Craig Crawford, Collegiate

Effect of Competition Stakes on High School Student-Athlete Stress Levels

Stress among adolescents is a prevalent concern. Student-athletes often face elevated levels of adolescent stress as a result of their added athletic responsibilities. Although extensive research exists on the relationship between athletics and academic performance, there is a lack of research on how varying levels of competition can affect stress among student-athletes. Additionally, while much of the existing research focuses on seasonal stress patterns (on- versus off-season), there is limited research on how varying competition levels across weeks influence stress. The purpose of this study is to determine whether the level of athletic competition, defined as no competition, low-level competition, or high-level competition, contributes to high school student-athletes' overall stress level during a given week. An additional measure of stress, perceived external pressure levels to perform from coaches, parents, and peers, is also evaluated across competition weeks. To collect this data, student-athletes completed a survey where they reported their Competition Level and, using a scale from 1 to 3, rated their Overall Perceived Stress Level and their External Pressure Level from parents, coaches, and peers. The survey also attained consent from the subject and their parents. Surveys were administered twice during the fall athletic season, with a different group of subjects for each round of surveys. The findings showed no significant variation in Overall Stress based on Level of Competition, resulting in a failure to reject the null hypothesis. However, a significant difference was found in the External Pressure Levels student-athletes experienced, depending on their competition level. This result suggests that athletes participating in higher-level competition weeks often face greater pressure from coaches, parents, or peers. These results imply that while student-athletes' perceived overall stress may not change based on the level of competition, specific components of stress, such as external pressure, may increase during higher competition levels, highlighting the need for coaches and schools to monitor expectations during demanding weeks. These findings also indicated that evaluating only overall stress measures may overlook specific components of stress, suggesting that future research should investigate additional layers of stress measures in student-athletes. This study faces potential limitations such as the method of self-reporting stress levels, variability in participants' interpretation of stress, and a smaller-than-ideal sample size.

Olihnenco Abigail, Mills E. Godwin High School
The Effect of Distractions on Reading Comprehension

The purpose of this experiment was to find the effects of different distractions on reading comprehension. Recently, the rise of social media and easy access to knowledge have encouraged students to obtain information at their preferred time. This has caused distractions in learning environments and created fragmented learning. Participants read three different passages and completed a reading comprehension test based on the passages given. Two types of distractions were used, one being a YouTube video and the other being a set of twenty questions asked, while participants simultaneously read the passage. The control was no distractions while reading a passage. It was hypothesized that participants who were asked a set of questions while reading the passage would score the lowest on the comprehension test. The results revealed through the mean that participants' reading comprehension was affected by distractions. A t-test was done on the data and revealed that the data was not statistically significant, and the research hypothesis was not supported. It is believed that the results are due to the fact that working memory capacity is different for each participant and divided attention causes information from one task to interfere with the other. This research could lead to further studies that investigate and compare reading comprehension for individuals with diagnosed attention difficulties and those without.

Psychology B (HS PSY-B)

Psychology Award
First Place
Beazley Tinsley, Chesapeake Bay Governor's School
A Correlation between Short-Term and Working Memory and Cognitive Ability in Children

Memory is a fundamental part of cognitive development and academic performance in children. Prior research suggests that working-memory is strongly correlated with general cognitive ability; however, fewer studies have tested this relationship in elementary aged children. This study investigates the correlation between short-term, working-memory, and cognitive ability in elementary aged children aged 7-8, while also looking for potential gender differences. I used a sample of convenience of 71 elementary students. All the participants completed auditory, visual, and picture memory tasks, and their performance was correlated with an already obtained Cognitive Abilities Test Score (CoGat) given by the school. Pearson's r was used to analyze how strong the correlations were. Results revealed positive correlations between memory performance and cognitive ability. Auditory working-memory showed the strongest and most consistent correlation with CoGat scores, while Picture memory was moderately positive and visual still being positive but much weaker. Gender analysis indicated that males showed a stronger correlation in picture memory while females demonstrated a stronger correlation in visual and auditory tasks. Findings support my hypothesis that working-memory is positively correlated to cognitive ability in elementary aged children. These results suggest the importance of supporting multiple memory systems in education. This study contributes to understanding relationships between memory and cognitive ability and supports further research on

memory-based instructional strategies and looking at the correlations on a broader scale.

Second Place

Turnbow Carrington, Central Virginia Governor's School for Science and Technology

How Age Affects the Perception of Stereotypes

The purpose of this study was to look at the development, prevalence, and prominence of high school stereotypes across one's lifetime and life experiences. This study was conducted at a local elementary school and used adults within the community, splitting them into two separate groups. They took the same survey created to find the ability to accurately identify each stereotype and to find common adjectives related to that stereotype. The accuracy of each stereotype for both groups was then put into percentages, and a Chi Square Test for Independence was performed. The resulting Chi Square Test for Independence, using an alpha value of .05, produced a p-value of .17. These results showed that there was not any statistical significance and did not support the research hypothesis which stated, if we survey different age groups about the prominence of their idea of stereotypes, then the adults' stereotype identifications will be more noticeable, defined, and prevalent as opposed to the elementary-aged students. In summation, this study supported the idea that stereotypes are formed in adolescence and continue into adulthood with the same level of intensity.

Third Place

Meadows Riley, Central Virginia Governor's School for Science and Technology

Psychometric Relationships Among Athletic Performance Levels, Mood, and Academic Performance in High School Student Athletes

The purpose of this research was to study the relationships between athletic performance/anxiety with academic performance and mood variables, along with how these variables vary between practice and game days. Participants were recruited from a local high school to complete four surveys on two occasions. The surveys included the GAD-7 general anxiety scale, the SAS-2 sports anxiety scale, the SPANE (Scale of Positive and Negative Experience), and an academic performance scale. Each participant completed the surveys twice: once on a practice day and once on a game day. After data collection, four paired t-tests were run to examine differences between scoring on practice and game days. Only one statistically significant result was found, with a p-value of .01 (α=.05) for the general anxiety scale. Next, six regressions were run to show the relationships between variables, specifically the correlation between sports-related anxiety and other variables. Two statistically significant relationships, with an r2 value of .72 for sports-related anxiety and academic performance and an r2 value of .366 for sports-related anxiety and general anxiety. These findings suggest that general anxiety is a significant factor and that higher sports-related anxiety may act as a motivator for academic performance. These results suggested that the hypothesis, If adolescent athletes perceive their athletic performance to be low, then their mood states, academic performance, and anxiety levels will have a direct positive relationship was partially supported. This study showed the effect of sport anxiety on different aspects of life, and how they situationally vary.

Honorable Mention
Blackwood Ellie, Collegiate
How Heart Rate Changes While Handling Biological Stimuli in Relation to Curiosity and Nervousness in Children and Teens

This experiment investigates how age affects curiosity when people are exposed to darkling beetle larvae (mealworms). Curiosity is often linked to emotional and physiological responses, and one way to measure curiosity is through changes in heart rate. When someone is presented with something new or interesting, their heart rate can increase due to excitement or attention. In this study, participants from two different age groups: elementary and high school, held beetle larvae while their heart rates were monitored. Each participant's resting heart rate was recorded first, and then their heart rate during the safe exposure to the insects. The spike in their heart rate is used to see how curiosity affects physiology. Results show percent change in heart rate does not significantly differ between age groups (even though younger students have a significantly higher max heart rate). However, age does significantly affect reported feelings of curiosity and nervousness. By comparing the heart rate changes between age groups, this experiment explores how curiosity changes with development to adolescence. Curiosity is a key component in learning, fostering creativity and engagement in children; and so studies of this nature are vital to supporting educational strategies.

Honorable Mention
Conner Catherine, Collegiate
Effect of Background Music in a Video on Heart Rate

Music has a great effect on human brains, hearts, and emotions. Through music, people build connections, neural pathways are shaped, and stress decreases (Zaatar *et al,* 2023). Music has a wide variety of uses. Understanding the effects different types of music has on the human body leads to better use of music, but this understanding can also be used to manipulate people through marketing techniques that aim to play on the emotions of the consumer (Dogaru *et al,* 2024). By having a greater knowledge of the effect of different types of background music on human physiology, people can become more aware of the use of music in the media and whether such music could be controlling their decisions by manipulating their emotions. This experiment aims to observe whether the background music in video has an effect on a person's heart rate, and if so, which type of music has the greatest effect. A video was made and had four types of background music added: "calm/sad"; "happy"; "scary"; and no music as the control. Groups of two to six participants would watch one of the four videos, using Innovo iP900AP Finger Pulse Oximeter heart rate monitors connected to the Beyond Oximeter app on iPads to track their initial heart rate and heart rate during the video. After watching the video, participants filled out a Google Form with their data, type of music, and their own classification of the music. The forms' results and data were placed in a Google Spreadsheet to be analyzed. Background music showed a significant effect on heart rate. "Happy" music had the greatest percent decrease with 8.76 ± 3.88% decrease in heart rate, while "scary" music had the greatest increase with an average of 6.67 ± 4.23% increase in heart rate. Participants who watched the video

with “calm/sad” music or the control of no music showed little change in heart rates, both under 2%. With an understanding of the experiment's significant results, the media industry could become more knowledgeable about the types of music to use in their content. This knowledge could both benefit and disadvantage creators and viewers. Creators could better utilize music to design a more immersive experience; however, creators could also employ music to manipulate viewers into making choices they might not otherwise make. Viewers could have better media through creators' understanding of music; however, if creators could use music to manipulate them, the viewers’ behaviors and perceptions of the world could be influenced negatively.

Honorable Mention

Jones Madison, Chesapeake Bay Governor’s School

How Does Phone Use in Adolescents Affect Mood and Sleep Patterns?

Humans have largely integrated technology into our everyday lives, especially when it comes to social media. However, studies have shown that prolonged exposure to social media can cause adverse effects in adolescents, manifesting in poor sleep quality and poor mood, and that abstinence from social media can promote positive effects, such as good sleep quality and good mood. To determine whether this was the case, this study was conducted using student participants who were instructed to complete surveys containing questions regarding their weekly screen time and self-reported rest quality, happiness, boredom, and stress. Each week as the study progressed, new intervention methods were introduced in the form of weekly or daily reminders. This study showed that there is a correlation between reducing screen time and a change in sleep quality and mood, but the results were not always positive changes, with some categories showing a decrease in wellbeing as the study progressed. This study was important because it is crucial to find if the intergeneration of technology in daily life has had lasting impacts on the way minds and bodies process concepts such as motivation, addiction, and reward, especially when it is taken away.

Bryant Carter, Central Virginia Governor’s School for Science and Technology

Examining how the Overuse of Generative Artificial Intelligence Technology Affects Human Cognitive Abilities

The purpose of this experiment was to determine the relationship between cognitive decline and students who are dependent on the use of AI in school assignments. Participants were recruited from three different high schools, with a total of eight participating individuals. Participants were asked to complete a questionnaire on their AI use and then subjected to a memory examination and a prompt response. Scores from those tests were then recorded and analyzed using an ANOVA test, with a resulting p-value of .54 from the memory examination scores, and .73 from the prompt response scores ($\alpha = .05$), which did not provide significant results. The research hypothesis stating that, if students who regularly use AI to complete school assignments are tested against students who do not, the average scores of those tests of the AI-Use group will be significantly lower than the scores of the Non-AI-Use group, was not supported by the data collected and examined. In summary, an individual’s amount of AI use did not have a significant impact on their cognitive abilities in this study. However,

further study is necessary on the manner in which artificial intelligence is used and the impacts it has on cognition and learning.

Correa-Loredo Kevin, Central Virginia Governor's School for Science and Technology
Evaluating Consumer Home Design Preferences to Guide Housing Industry Decisions

The purpose of this research was to examine whether there was a significant difference in consumer preferences for various exterior and interior home styles. The hypothesis of this research was: If the citizens from cities and counties of the Central Virginia region are presented with a variety of common house styles, both interior and exterior, the expectation is that the majority will rank the farmhouse style higher than the others, both interior and exterior, which they desire the most. Residents in the Central Virginia area were surveyed to rank ten selected styles for both the exterior and interior of homes, from the most preferred to the least preferred. A total of 56 data points were collected for both the exterior and interior styles. A Chi-square test of independence assessed the relationship between demographics and preferred styles among participants, yielding a p-value of 1, indicating no significant difference when compared to the alpha value of .05. A Chi-square goodness of fit test was conducted for both the exterior and interior styles. The results yielded p-values of less than .001 for both tests, as compared to an alpha value of .05. This indicated that there were significant differences in preference data, which partially supported the research hypothesis. The most preferred exterior style was Craftsman, while the most preferred interior style was Modern Farmhouse. The findings provided valuable insights for professionals in the housing industry when evaluating which styles to build or design.

Freday Evelyn, Blacksburg High School
Examining the Linkage Between Digital Influence and Increasing Student Accommodations in MONTGOMERY COUNTY

ADHD is a common mental health disorder in adolescents, and rates have progressively increased worldwide throughout recent years. The primary cause of this increase has yet to be identified, though there are many current speculations of what the primary cause could be. Previous research has shown that screen usage tends to correlate positively with ADHD, especially in younger children. This study investigated whether or not there was a positive correlation between increased outside-of-school screen usage during COVID-19 virtual learning and increasing ADHD 504 plan rates in grade levels 4, 7, 9 and 12. Additionally, this study investigated whether or not Blacksburg schools had a significantly higher number of ADHD 504 plan rates than other schools in Montgomery County, Virginia. The tests performed in this study show a positive correlation between the years of COVID-19 virtual learning and rising ADHD/Attention 504 plan rates. This suggests that screen usage correlates positively overall with ADHD rates, and that outside-of-school Chromebook usage correlates positively with rising 504 plan rates. This study cannot prove causation, as it is based on a correlation matrix. External factors such as home environment, amount of screen time prior to COVID-19, and economic status were not measured in this analysis, which could affect the data present. Overall, the results of this study broaden the study of the primary cause of ADHD and increase awareness in this field.

Lubik Natasha, Collegiate

Effect of Stress and Anxiety on Academic Performance

Stress among high school students is a growing problem. Many students are unaware of their stress levels, let alone understand the importance of managing their stress. Experiencing a consistent amount of stress takes a toll on the human body, leading to hypertension and the deterioration of metabolic functions. More importantly, for students, stress inhibits the ability to process and recall previously studied information, which makes it increasingly difficult to perform well on assessments. This study examines how stress affects test scores on an Anatomy assessment with questions that consist predominantly of matching terms to parts of the human body based on memorization. After the assessment, students anonymously reported their scores, stress level, sleep average the night before the test, and, in general, the number of hours spent on after-school activities, and the number of hours spent on homework. The results show that students who reported high stress levels performed significantly less well than expected, if students perform similarly under low stress as they do under high stress. Students who scored between 60-69% spent the most time on afterschool activities, while the students who scored 100% spent less time on afterschool activities. The students with high scores reported that they normally study days in advance and stayed consistent with this method for the assessment. The students with low scores changed their study habits from their norm. In conclusion, stress may affect test scores, but other factors, such as sleep, study habits, and time spent on activities together, have a greater impact.

Martz-Brooks Ethan, Central Virginia Governor's School for Science and Technology

How does the Placebo and Nacebo Effect affect your shooting form?

This study examined whether belief in the effectiveness of a wrist-worn product could influence the shooting accuracy of high-school basketball players. Participants were randomly assigned to placebo, nocebo, or no-effect conditions and completed a baseline free-throw assessment before receiving a wristband paired with condition-specific information. A second shooting assessment followed to measure changes in performance. Descriptive and inferential analyses were used to evaluate whether belief-based expectations produced measurable differences among the three groups. Statistical testing showed no significant changes in accuracy following the intervention, and the hypothesis that belief alone would alter shooting performance was not supported. Overall, the findings indicate that expectations surrounding a simple wrist-based product did not meaningfully affect free-throw accuracy under the conditions of this experiment.

Misra Anushka, Gainesville High School

Is Your Internal Clock Hypnotized? The Effect of Psychological Beliefs on Circadian Rhythm

Circadian Rhythm is the body's 24-hour clock which regulates the sleep-wake cycle, and bodily processes. Factors that can affect circadian rhythm include- light, food, stress, physical activity, mental health, and temperature. Importantly, the circadian rhythm is known to affect performance and brain health. The purpose of the experiment was to investigate whether psychological beliefs affect one's circadian rhythm. The hypothesis was- If one has a psychological belief regarding a factor of

circadian rhythm, then it will influence their circadian rhythm. 62 subjects completed a consent form and a comprehensive questionnaire which asked the subjects questions regarding aspects of circadian rhythm and their beliefs. The responses were analyzed, and quantitative data was collected using the numerical ranking scale provided to answer certain questions. After analyzing the results, data consistently showed that the majority of participants seemed to have the same or very similar realities compared to their beliefs. For example, 100% of participants who self-identified their chronotype as a “morning person” reported to have strongly agreed when asked if “being a morning person is better” and all subjects' number of actual sleep hours were within a 1-hour margin of their perceived sleep needs. Furthermore, data showed that of the subjects who ranked their sleep quality as fair or higher, about 78% had coinciding beliefs and circadian rhythm. It was also shown that the subjects with the same psychological beliefs and circadian rhythm tended to have a normal sleepiness level (based on the Epworth Sleepiness Scale) and were more alert throughout the day. The *t*Test scores proved the significance of the data collected. Data proved the hypothesis correct and suggests that subjects who satisfied their psychological beliefs proved to have supported better sleep quality, alertness and overall well-being.

Yong Mu Zhen, Mills E. Godwin High School

The Effect of AI Model on Human Recognition of Text

The purpose of this experiment was to find the effect of different AI models on the ability to recognize and differentiate between AI- and human written text. Recently, it has become extremely easy to be tricked by AI-written texts and think they’re human written, which is why it’s important to be able to differentiate the two. In the experiment, a survey was conducted where 26 participants in the same adolescent age range were asked to determine whether 20 texts presented were AI- or human written. A control group of human written texts were put in the survey, alongside texts generated by the 3 AI models, those being ChatGPT, Gemini, and Copilot. It was hypothesized that ChatGPT would be able to mimic human-written text the best out of the three AI models used in the experiment.

The results revealed that ChatGPT mimicked human writing the best, with over 75% of participants guessing incorrectly, supporting the hypothesis. Copilot was also mistaken for human written texts most the time, however, ChatGPT was more consistent in comparison, having a smaller standard deviation; meanwhile, Gemini was identified as AI the most, the results being consistent across all texts. It is believed that ChatGPT had the best results out of the three AI models since it has the most consistent writing style, alongside it being the first to be released. Further studies could include researching the effect of age on ability to detect AI, or the ability of AI models to generate different writing styles.

Statistical Analysis & Inferences (HS SAI)

Statistical Analysis & Inferences (HS SAI)

Statistics Award
First Place
Yang Daxing, Mathematics and Science Academy at Ocean Lakes High School
Historical Redlining and Urban Heat Islands in Norfolk, Virginia

Urban heat islands (UHIs) disproportionately affect low-income communities and communities of color across the United States. This study investigated whether historical redlining practices from the 1930s continue to influence contemporary land surface temperature patterns in Norfolk, Virginia. Between June and August 2024, satellite-derived land surface temperature data was collected and analyzed across 42 historically graded neighborhoods using the Homeowners' Loan Corporation (HOLC) residential security maps. Spatial analysis in QGIS calculated mean temperatures, tree canopy percentages, and impervious surface coverage for each HOLC zone (Categorized by Grades A through D). Statistical analysis included independent t-tests, one-way ANOVA, Pearson correlations, and multiple linear regression. Results demonstrated that formerly redlined (Grade D) neighborhoods experienced significantly higher mean land surface temperatures compared to Grade A areas. A One-way ANOVA confirmed significant differences across all HOLC grades and Tree canopy coverage showed a strong negative correlation with temperature. Multiple regression analysis ($R^2 = 0.73$, $p < 0.001$) identified tree canopy as the strongest predictor, followed by HOLC grade ($\beta = 0.32$, $p < 0.001$). These findings indicate that discriminatory policies established 90 years ago continue to create measurable environmental disparities, supporting the need for targeted urban heat mitigation strategies in historically disadvantaged neighborhoods.

Second Place
Foutz Vivian, Western Albemarle High School
A Statistical Framework for Quantifying Lifestyle as Behavioral DNA from Population-Scale Mobility Data

Lifestyle is widely invoked to *conceptually* explain human behavior but remains *empirically* unvalidated. Existing approaches relying on small-scale, self-reported surveys or demographic proxies fail to capture the temporal, latent structure of behavior. This study introduces a novel statistical framework integrating machine learning, natural experiment, and causal inference. Leveraging 58 million privacy-compliant, population-scale mobility records, the analyses (1) uncover *9 distinct lifestyles*, and (2) demonstrate these lifestyles' power in *predicting human response* to diverse environmental shocks. Three hypotheses are tested and supported: lifestyles are *temporally stable*, *irreducible to sociodemographics*, and *predictive of behavioral adaptability* to environmental shifts *beyond access*, hence challenging the access-based models by showing that opportunity alone (e.g., fresh grocery nearby) does not determine adaptation (living a healthier lifestyle). These findings offer first population-scale evidence that latent behavioral structure functions as a foundational "behavioral DNA" governing human activity, advancing research in statistics, economics, business, public health, and computational social science. More broadly, it offers a scalable framework for improving policymaking, empowering behavior-aligned, precision interventions, thereby increasing policy efficacy and societal impact.

Third Place

Vijay Dhruv, Mills E. Godwin High School

Transcriptomic Analysis of Skeletal Muscle Adaptation to Injury and Resistance Exercise

Muscle adapts well to physical stress, adjusting how genes behave, changing cells, and reorganizing tissue layout. Following strength training or damage, shifts in genetic activity guide cell awakening, muscle fiber formation, building proteins, alongside modifications in structural support around cells. Here, researchers used computational tools to explore data from two publicly available Gene Expression Omnibus (GEO) datasets, GDS234 tracks recovery after injury over time, while GDS278 captures gene behavior post-strength workout. Patterns of change in central control genes like Pax7, Myod1, Myog, Igf1, and Col1a1 unfolded differently depending on condition and timing. Regeneration showed clear stages marked by unique gene behaviors; workouts sparked notable increases in growth-related and muscle-forming signals. Gene activity is sequenced throughout time. By using computational tools, such as these datasets with R analysis, researchers uncover how muscles change at the molecular level, revealing patterns not easily seen otherwise. This also highlights which molecules can be used to enhance muscle regeneration or hypertrophy (muscle growth) best, and when in relation to the time since injury/hypertrophic stimulus, enhancing lifestyle through muscle growth or regeneration. Outcomes point toward shared biological mechanisms useful for refining recovery strategies while improving how training adapts over time, specifically for hypertrophy and muscle repair.

Honorable Mention

Marsden Madilyn, Blacksburg High School

Roots to Results: Understanding the Impacts of Preschool on At-risk Students' Kindergarten Success

This study examines the relationship between attendance in Montgomery County Public Schools' (MCPS) state-funded, at-risk pre-kindergarten program and early academic performance in kindergarten and first grade. The purpose of the study is to determine whether participation in the MCPS at-risk pre-K program is associated with measurable academic advantages or disadvantages when compared to peers who did not attend the program. Academic performance was evaluated using standardized reading, writing, and mathematics assessment scores. The study sample consisted of 98 MCPS students aged 5–7, including 42 students who attended the MCPS Early Childhood Education At-risk Pre-K program and 56 students who did not. Student data was obtained through school assessment databases and survey responses that accounted for potential confounding variables such as socioeconomic status, parental education level, language spoken at home, and IEP status. A series of two-sample t-tests were conducted to compare academic outcomes between the two groups. Statistical analyses revealed no significant differences in VALLSS test score growth between at-risk students who attended the MCPS at-risk pre-K program and those who did not. These findings suggest that participation in the MCPS-funded pre-K program has limited to no impact on early academic achievement in at-risk students as measured in kindergarten and first grade. The results underscore the importance of

reevaluating early childhood education programs and their effectiveness in supporting at-risk students, and they may help inform families and educators when considering preschool options and early intervention strategies.

Ashton Loralai, Central Virginia Governor's School for Science and Technology
The Impact of the COVID-19 Pandemic on Student Enrollment in Arts Programs: A Comparative Analysis Before, During, and After the Pandemic

The purpose of this research was to see if the student participation rates in different art programs had rebounded since the 2020 Covid-19 pandemic. The research hypothesis, which stated American art programs during the 2020-2021 school year would see a significant decrease in student participation and would see an increase in the years after, was tested by using a national arts education database with data points from three different states and 5 different years. Next, the data points were analyzed using a one-way ANOVA. The results of the ANOVA produced a p-value of .86 which did not show significance compared to the alpha value of .05 and therefore did not support my research hypothesis. Although the statistical test was not statistically significant, visual trends suggested possible recovery patterns. In summation, Covid-19 partially had an effect on art student participation.

Deane Sydney, Blacksburg High School
Clarity, Comfort, and Stress: Understanding Students' Experiences with Generative AI in Academic Work

This research explores how students experience comfort and stress when using Generative AI for academic work. This project is conducted using a survey, and the responses will help me understand how students use generative AI in their coursework, and how policy clarity and familiarity with these tools influence stress, comfort, and perceptions of fairness. Generative AI technology is rapidly changing the world we live in, and it has created both opportunities and challenges. One area where these changes are very obvious is education. While GenAI has the potential to become an important tool in the learning process, its use in schools has been met with mixed reactions. While focusing on AI in general, this study also dives deeper into the effect of policy clarity. Having a clear or an unclear policy can have both negative and positive challenges. This study aims to determine which causes a greater impact and if that impact is negative or positive. The results of this study could be used to inform university policies, with the goal of helping professors change their policies to be clearer, and more helpful for students.

Joyasawal Shriyans, Mills E. Godwin High School
Predicting Chromosomal Conformation Changes Using Deep Learning Models

Three-dimensional genome structure plays a vital role in controlling genome expression, chromatin accessibility, and cellular stability. Chromosomal structure disruption has been implicated in genomic instability, transcriptional dysregulation, and disease pathogenesis. Experimental methods such as Hi-C are available for studying chromosomal structures but are time-consuming and costly. Computational modeling provides a cost-effective and efficient approach for studying structural genome dynamics. The objectives of this study were to investigate whether increased levels of

cellular stress are correlated with increased levels of predicted chromosomal rearrangements using a Convolutional Neural Network (CNN) approach with publicly available Hi-C data. Hi-C data was downloaded from publicly available genomic data repositories and preprocessed for normalization and removal of noise. A CNN was designed and trained on the preprocessed data to identify spatial interaction features indicative of structural genome rearrangements. The trained CNN was then applied to predict chromosomal rearrangements in four different conditions: Control, Low Stress, Medium Stress, and High Stress. Group means were compared, and independent-samples t-tests were conducted to determine statistical significance. The means for predicted chromosomal rearrangements were calculated for all four conditions and were found to increase from Control ($M = 0.21$) to High Stress ($M = 0.79$). Statistical tests were conducted to determine if there were any statistically significant differences between conditions and Control. The means were significantly different from Control for High Stress ($t(4) = -27.86$, $p < 0.001$). A clear dose-response relationship was observed. Increased cellular stress levels are correlated with increased predicted levels of disruption in 3D chromosomal structures. These data support our hypothesis that increased levels of cellular stress result in increased levels of disruption in genome structural integrity.

Sheets Addison, Southwest Virginia Governor's School

Determining Funding Strategies at Southwest Virginia Animal Shelters

Animal shelters play a crucial role in lowering animal overpopulation in the community by rescuing animals and rehousing them. To accomplish this, these shelters utilize adoptions and spay/neuter programs, but without the proper funding, they are forced to euthanize or turn away animals to avoid closure. This project analyzed the funding sources and methods used by Southwest Virginia animal shelters. Questionnaires were distributed to each shelter with questions asking them to rank their funding sources based on the percentage of total funding and list methods used to collect those funding sources effectively. The rankings were placed into a chi-squared test of homogeneity. After gathering the test's results, the null hypothesis was rejected with a p-value of 0.0005, and the donations/gifts category was established to be the highest-ranking funding source throughout the shelters. This supported the hypothesis and suggested that the most effective methods for collecting funding were used towards donations. The methods used for donations were grouped into five categories and placed into a chi-squared goodness-of-fit test. The results supported the null hypothesis with a p-value of 0.6005, which concluded that the methods given by the animal shelters were evenly distributed. This test supported the hypothesis, and the methods were deemed effective in collecting funding across Southwest Virginia animal shelters. As such, animal shelters should consider implementing these methods to increase funding. Additional research in different areas is needed to determine universal funding methods.

Zoology (HS ZOO-A)

VABE Zoology Award
First Place
Porter Jack, Collegiate
Impacts of Lead on the Cognitive Function of the Flatworm, Girardia tigrine

Heavy metals have been found to have adverse cognitive effects on humans. Similarly, this study aims to uncover lead's impact on the memory of *Girardia tigrine,* or brown planaria. During the entire experiment, the organisms were tested in a feeding chamber to understand lead's impact on the cognitive function of planaria. The chamber was designed to demonstrate planarian's ability to learn simple tasks, while also creating a way to simply test lead-induced differences. Each group of organisms were introduced to food as a reward that was placed in a plastic straw. Contact visits were defined as visits to the location, while feeding was defined as eating the food. The goal of this first phase - the learning phase - was to train the planaria to associate the location with food. That way, post-lead exposure, the memory function of impacted groups could be assessed in relation to their ability to remember the location of food. Following the learning phase, each group was given the same feeding chamber, but this time without food, in order to demonstrate a learned behavior. This phase was called the proof phase. Even without the food reward in the chamber, the subjects demonstrated their learned behavior following the three-day learning period. Half of the groups were then transferred into a lead solution for three days, known as the exposure phase. The other groups were kept in conditions identical to the first phases. Again, the groups were given the identical feeding chamber without food in order to assess the impacts of lead on the exposed groups. Statistical analysis ($X^2_{calculated} = 6.55 > X^2_{critical} = 5.412$, df = 1, p = 0.02), shows that when comparing the fraction of total visits in the proof and learning phases to the exposure phase, heavy metals had a negative impact on the memory of planaria. During the exposure phase, the fraction of visits out of a total of 18 planaria was 0.44 for the control group, while in the group exposed to lead the fraction dropped to 0.17. This finding highlights the important impacts heavy metals have on cognitive function, and the ramifications lead has on aquatic environments.

Second Place
Pittarelli Arianna, Central Virginia Governor's School for Science and Technology
Effects of Synthetic and Natural Sugars on Reproduction and Development in Drosophila melanogaster

By studying synthetic, regular, or no-sugar diets, this study aimed to find out if these sugars affect lifespans and generational health in *Drosophila melanogaster*. Xylitol and table sugar in .5 mg amounts were all mixed into an existing molasses food source, along with a group with no added sugar for the control. Three flies (two males and one virgin female) were added to start the reproduction process. After 2-3 days, the eggs were counted under a microscope, and the parents were taken out to be observed separately from the offspring. An ANOVA tested differences between groups. The p-values of the eggs and adults produced, respectively, were .10 and .66. Compared to an alpha value of .05, these results were not significant. The experimental data somewhat supported the research hypothesis that stated that if flies are exposed to different types of added sugar or no sugar, the xylitol group will produce the least number of eggs and adults. The xylitol group had the lowest

average number (69.2) of eggs and adults that survived. Following these findings, a regression was run to understand if there was a relationship between parent survival and the number of eggs and adults produced. There was a significant positive relationship between the two variables with a p-value less than .01. To summarize, this research highlights that dietary and nutritional choices impact more than just the individual; parental fitness serves as the foundation of the lives of the future generation.

Third Place

Gitre Xavier, Blacksburg High School

Parent-absent begging in Eastern Bluebirds (Sialis sialis): An exploratory study

Traditional begging signals given by the altricial young of birds serve to communicate need to parents and solicit provisions during feeding visits. Such signals often incur costs, like predation costs, which should hypothetically limit their prevalence. Counterintuitively, however, there also exist a great number of taxa who's young beg in the absence of their parents. There has been much debate in the literature regarding the costs, functions, and structures of those signals with little clear synthesis. This system presents an interesting insight into how, at both the evolutionary and individual nestling levels, behaviors such as begging may be modulated in response to shifting natural history trade-offs. Here, I conduct an exploratory study of parent-absent begging (PAB) in a species in which it has not been officially documented to understand what nesting or environmental variables are associated with it, the extent to which it's a costly behavior, and how PAB varies structurally from other begging types. I find evidence in the observed patterns of PAB that such begging may result from errant responses to stimuli potentially representing parental visits, possibly a result of a decreased "stimulus threshold" in hungrier nestlings and greater cognitive constraints on younger nestlings, and I find evidence supporting PAB as an honest signal of hunger. I also find that the structures of PAB bouts have characteristics consistent with adaptations meant to prevent predator localization. Finally, in my sample, I do not detect a significant cost to giving PAB, potentially as a result of these adaptations, but equally possibly because of limitations of this study. More broadly, the present study provides an insight into a model system for understanding behavioral and life-history tradeoffs, findings from which could ultimately be upscaled to understand population-level responses to a changing environment.

Honorable Mention

Carothers Tovia, Central Virginia Governor's School for Science and Technology *The Effect of Increased Activity on the Heart Rate Variability and Lifespan of Daphnia magna*

The purpose of this study was to examine the impact of varying activity levels on heart rate variability (HRV) and the lifespan of *Daphnia magna*. This experiment was conducted at a local high school laboratory during November of 2025. Daphnia were divided into three activity level groups (active, semi-active, and inactive) with the activity being induced by briefly stirring the water once per day. Heart rates were collected weekly using microscopic observation, and HRV was determined by measuring the time interval between heartbeats. Lifespan was recorded for each individual. A one-way ANOVA compared HRV across activity level groups and revealed a statistically

significant difference, a p-value of less than .01, with an alpha level of .05. A post-hoc Tukey test indicated that the most active group exhibited significantly higher HRV than the other groups, supporting the first part of the research hypothesis. However, a separate one-way ANOVA comparing lifespan across activity groups showed no statistically significant difference, with a p-value of .24. This finding did not support the second part of the research hypothesis, that the group with the highest HRV would have the longest lifespan. Overall, the increased activity level contributed to enhanced HRV, but the higher HRV alone did not lead to a longer lifespan.

Honorable Mention

Kumar Priya, Maggie L. Walker Governor's School

The Effect of different concentrations of resveratrol on the heart rate of the Daphnia magna

Resveratrol is a polyphenol which naturally occurs in plant species like red grapes and seeds and its derivative red wine. Resveratrol has broad biological activity. It is known to have antioxidant, anticancer, anti-inflammatory, cardioprotective, neuroprotective, and antimicrobial properties. Few studies have investigated the heart rate reducing effect of resveratrol. Lowering the heart rate is beneficial for individuals with cardiovascular/heart disease like arrhythmias and heart failure and for conditions like anxiety. The purpose of the experiment was to observe the effect of resveratrol on the heart rate of Daphnia magna. The hypothesis of the experiment was, "If the Daphnia magna is exposed to different concentrations of resveratrol, then the heart rate of the Daphnia magna will decrease." Ten trials for each concentration were conducted. The average heart rate of Daphnia magna in spring water (control) after 10 trials was 214 beats/min. The average heart rate of the Daphnia magna for 1 drop of a 1:1 resveratrol dilution, 5x dilution, and 10x dilution were 171.2, 182.8, and 193.6 beats/min respectively. Statistical analysis was performed using one-way ANOVA to investigate if the concentration of the resveratrol, not just the resveratrol itself, is significant to the change observed in the Daphnia's heart rate. The f-value for the test was 243.53, while the p-value was 2.22e-16. As the results of the ANOVA indicated statistically significant difference, a Tukey Honestly Significant Difference (HSD) test was also performed to see which specific pairs of groups differed. All pairwise comparisons were significant with a p-value of not just < 0.05, but < 0.000001. From this analysis, it is confirmed that there were statistically significant changes between the heart rate values for the Daphnia between all groups of the independent variable and the control group. The data and results strongly support the hypothesis that resveratrol decreases the heart rate of Daphnia magna, and it shows a clear dose-response relationship. The experiment supports the conclusion that resveratrol reduces the heart rate. Thus, it potentially could be used as a natural remedy for higher heart rate caused by conditions like anxiety and stress in humans. It may be beneficial for reducing heart rate in primary cardiac conditions like arrhythmias and heart failure. Further rigorous randomized clinical studies should be done in various other organisms as well as human subjects.

Honorable Mention

Lauria-Leighton Liam, Southwest Virginia Governor's School

Hermit Crab Claw Strength as Related to Body Weight

Filling the role of scavengers, shell recyclers, and providers of support for small symbiotic organisms, hermit crabs are vital parts of coastal and intertidal ecosystems (Williams & McDermott, 2004). Claw strength is directly related to the crab's ability to survive, providing them with defenses and a reliable way to access food. Taking into account the strong positive correlation found between pinch force and weight in larger species of crab (Oka *et al.*, 2016), this study intended to demonstrate the same correlation in the terrestrial hermit crab species *Coenobita clypeatus.* Using McMaster-Carr pressure measuring paper on a sample of 24 terrestrial hermit crabs across three commercial locations, the force exertion of both cutter and crusher claws was measured. Vernier calipers and a Weigh Gram ingredient scale were used to record the length of the crab's dactyls in centimeters and their weight in grams. The pressure paper samples were photographed through a dissecting light microscope and converted to 8-bit images for color analysis - the degree of darkness indicated the amount of pressure exerted in PSI (pressure per square inch). It was found that the relationship between body weight and force exerted by the crusher claw is a weak, positive correlation (R^2 = 0.2081; p-value = 0.0377), and there is a weak to moderate positive correlation between dactyl length of crusher claws and weight (R^2 = 0.3568; p-value = 0.0026). Larger, stronger crabs would be more likely to survive in the wild, but in a captive environment, there are no driving forces to push them towards that goal, possibly explaining why there was such variation in strength. The exact force that *C. clypeatus* can exert is still unknown, and future research involving this subject will need to include the creation of a dynamometer small enough to fit into hermit crab claws.

Harry Nishal, Mills E. Godwin High School

The Effect of Polyvinyl Chloride Concentrations on Daphnia magna.

The experiment's purpose is to determine the effects of microplastics on *Daphnia magna*. The study was conducted to assess real world effects of microplastics on organisms living in aquatic environments due to the rise of plastic pollution. This study can help the environment by raising awareness about potential risks of microplastic pollution, allowing scientists and people around the world to make contributions in order to reduce plastic pollution. It was hypothesized that if the *Daphnia* were exposed to a higher concentration of microplastics, then the organisms will exhibit a higher heart rate and mortality. The Independent Variable (IV) levels were made by preparing four cups, containing different microplastic solutions with the control as 0.00 grams per liter solution to represent a pollution-free environment. 25 live *Daphnia* were carefully transferred to each cup from a pre-made culture to represent 25 trials. Results were acquired by using a microscope to read the *Daphnia* heartbeat while the mortality was recorded visually using flashlight from a phone. Results showed a greater concentration increases the organism's heartbeat and mortality. Conducted statistical tests showed a mixed variety of significance, with four out of the seven tests being significant. Higher concentrations of microplastics induced an elevated heart rate due to the adaptive stress response in *Daphnia*. Many organisms died from the IV levels 0.05 and 0.10 grams per liter, due to the organisms misinterpreting the microplastics as food. Further research can be to substitute *Daphnia* for Moina Salina, which can model marine organisms.

Hawkins Viyka, Central Virginia Governor's School for Science and Technology
Hermit Crab Reaction Time to Predators When Presented with Different Road Traffic Noise Frequencies

The purpose of this study was to determine if anthropogenic traffic noise slowed hermit crab reaction time to predators in comparison to reaction time when the noise was not present, to determine that humans should reduce anthropogenic sound pollution in the environment. Over the course of four Fridays, nine hermit crabs were exposed to four different traffic noise frequencies, 0 Hz, 700 Hz, 1000 Hz, and 1300 Hz, in a randomized order. During frequency exposure, predator-like actions were initiated by hand, and the reaction times of the crabs were recorded. The reaction times then underwent a single-factor ANOVA statistical analysis. The mean hermit crab reaction times were 0.6089 seconds (0 Hz), 0.7767 seconds (700 Hz), 0.7744 seconds (1000 Hz), and 0.8544 seconds (1300 Hz). The ANOVA analysis, with an alpha value of .05, revealed a p-value of .75, indicating a lack of significant difference between reaction times. These statistical values did not support the research hypothesis, which stated that the emission of anthropogenic traffic noise frequencies at a constant volume (60 dB) while initiating predator-like actions in hermit crabs' environments would increase the time taken by the hermit crabs to respond through hiding or retracting from the threat. In conclusion, traffic noise frequencies during predator-like actions did not significantly affect hermit crab reaction time. As mankind encroaches on animal natural habitats, this study is useful to understand animal behavior for the purpose of limiting the harmful effects of anthropogenic factors on animal environments.

Mann Maheep, Mills E. Godwin High School
The Effect of Honey on Cognitive Ability

Honey contains natural sugars, antioxidants, and polyphenols that support neural signaling and reduce oxidative stress, which may improve learning and memory. The purpose of this study was to determine the effect of different concentrations of honey on cognitive ability using *Drosophila melanogaster* as a model organism. Understanding how honey affects learning has potential implications for human health, as oxidative stress and reduced neural function are associated with memory decline and neurodegenerative disorders. The hypothesis stated that fruit flies fed 0.0021 mg of honey would complete a maze faster than flies fed lower concentrations or no honey. A control group receiving 0 mg of honey was used to establish baseline cognitive performance and allow for comparison to honey-treated groups. One hundred wingless fruit flies were evenly divided into four groups and fed 0 mg, 0.0007 mg, 0.0014 mg, or 0.0021 mg of honey mixed into their food. Cognitive ability was measured by recording the time required for each fly to complete a maze. Table 2 showed that mean completion time decreased as honey concentration increased, with the control group averaging 236.19 s and the 0.0021 mg group averaging 55.15 s. Inferential analysis using a t-test at $\alpha = 0.05$ indicated that all honey-treated groups differed significantly from the control ($p<0.05$). The results support the research hypothesis and suggest that higher honey concentrations improve cognitive performance due to increased reward-based learning and antioxidant activity in the nervous system.

Sura Tanmayee, Mills E. Godwin High School

The Effect Various Spices on Planarian Regeneration Rate

The purpose of this experiment was to find the effects of various spices on the regeneration rate of planarians. Planarians are studied for their remarkable ability to regenerate their axes after being cut. Spices have been used for centuries in remedies for their healing properties. The knowledge of which spices are the most helpful gives insight into ingredients for future medicines and recipes. Understanding the topic of regeneration and the effects of different ingredients is useful for future studies on regenerative medicine. It was hypothesized that turmeric solution would exhibit the fastest regeneration rate after planarians were amputated and exposed to various spice solutions. The control of this experiment is spring water. First, planarians are amputated in the same region behind the pharynx. Then, each group of planarians are placed in their respective petri dishes. Spice solutions are made and poured into each petri dish. The spices used are ginger, garlic, and turmeric. In twenty-five petri dishes there is ginger solution, in twenty-five dishes is garlic solution, in twenty-five dishes is turmeric solution, and in the last twenty-five dishes is spring water. The length of each planarian is measured every other day for nine days and recorded. Overall, the data of this experiment was not statistically significant with the exception of the turmeric solution versus the control. So, the null hypothesis was accepted. Turmeric did the best due to its abundance of curcuminoids that contain the best anti-inflammatory and wound healing properties.

Yella Misha, Mills E. Godwin High School

The Effect of Concentrations of Lidocaine Gel on the Reflex Suppression of Crickets

The purpose of this study was to find out how different concentrations of lidocaine gel affect nerve function, which was measured by timing the seconds until the hind-leg reflex was suppressed. Since lidocaine hinders communication between neurons, the hypothesis was that if the concentration of lidocaine increases, then the time until the hind-leg reflex was suppressed will decrease. Crickets were the optimal choice for this experiment as their nervous systems are simple, and they are ethically sustainable for testing. To conduct this investigation, the concentration of lidocaine gel was applied to the crickets, with dosages of 0%, 1%, 2.5%, and 5%. The gel was applied to the hind leg, and a timer started with a cap at 180 seconds. There was consistent stimulus in intervals to test the presence of the reflex. The 0% concentration served as a control to ensure there was a baseline for the reflex behaviors. After the analysis of the results, a clear inverse trend was observed between independent and dependent variable. The crickets who were exposed to higher concentrations of lidocaine had their reflexes suppressed quicker than the crickets who were exposed to lower concentrations. Furthermore, after the inferential statistics tests were performed, it was made apparent that all the tests rejected the null hypothesis, therefore concluding that all the data was significant. In conclusion, the data supports the hypothesis that concentration of lidocaine increases, then the time until the hind-leg reflex is suppressed will decrease. It can be concluded that this occurred due to the higher concentrations of lidocaine gel, blocking more sodium channels, therefore, hindering the escape reflex. These findings suggest that dosages do indeed play a vital role in nerve suppression The findings are also relevant to medical dosage accuracy and can aid safer anesthetic use. This

experiment also provides further knowledge into how anesthetic concentration may affect precision and accuracy in real-world applications.

Zoology (HS ZOO-B)

First Place

Rader Matthew, Central Virginia Governor's School for Science and Technology

Testing the Limits: Revival of Hypsibius exemplaris After Dehydration and Vacuum Exposure

Often referred to as "Water Bears", tardigrades are microscopic organisms capable of surviving harsh and extreme environmental conditions. They are capable of doing this by entering a state of anhydrobiosis called the tun state. This experiment tested whether direct exposure to a vacuum affected their ability to rehydrate and survive. Cultured Tardigrades were dehydrated, prompting them to enter tun state, then placed into a vacuum chamber for 1 day, 1 week, and 1 day, with a control group of no time. After each time interval, the tardigrades were removed, then rehydrated and observed to determine survival outcomes. The mean survival rates for each group was 93%, 86%, 93%, and 100% for the control group. Using descriptive statistics, similar survival and rehydration rates were observed. A One-Way ANOVA test was used to determine inferential analysis, with an alpha value of .05. A p-value of .41 showed that there was no statistically significant difference between the groups. Therefore, the research hypothesis that stated vacuum exposure time would impact survival and rehydration was not supported. Together, these findings suggest that tardigrades that have entered the tun state are capable of surviving and resisting vacuum conditions over the given periods of time. This study contributes to the understanding of tardigrades and their abilities to survive extreme environmental conditions, and it also demonstrates that further research that utilizes longer exposure time or other environmental stressors, such as extreme cold or radiation, may be required to determine measurable effects.

Second Place

Agrawal Agam, Mills E. Godwin High School

The Effect of Nutritional Composition of Lure on Ant Attraction

This experiment tested how the nutritional makeup of a lure (sugar, protein, or fat) affected attraction of Chestnut Carpenter ants by measuring both number of ants and time to arrival. Over two months, ants were exposed weekly to each lure, and because the aim was a direct comparison among treatments no blank control was used. It was hypothesized that the sugar lure would attract more ants and do so faster than the others. Results showed that, on average, the sugar lure attracted 6% more ants and reduced arrival time by 40% compared with the protein lure and attracted 13% more ants and reduced arrival time by 89% compared with the fat lure; 3 t-tests were conducted to indicate the statistically significant differences between the IV levels for both variables. These findings support the hypothesis that Chestnut Carpenter ants prefer sugar, likely because it provides quick, easily digestible energy, and suggest that sugar-based baits may be more effective for household ant management. Future work

should present multiple nutrients simultaneously to better simulate natural foraging and to test how competition among food types influences any preference.

Third Place

Wasson, Isla, Central Virginia Governor's School for Science and Technology

Azadirachtin as a Means of Reducing Fertility in Drosophila melanogaster

The purpose of this research was to determine the impact of topical exposure to increasing concentrations of the chemical azadirachtin on the reproductive output of *Drosophila melanogaster.* The experiment consisted of four groups of female fruit flies held at concentrations of 0mg/L, 1mg/L, 2.5mg/L, and 4mg/L for 48 hours before being mated with unexposed males. At the end of an additional 48 hours for mating, the eggs laid by the exposed females were counted. A one-way ANOVA test produced a p-value of .35, which, compared to the alpha value of .05, was not considerably low. This did not indicate a significant difference in the means of egg counts for the various concentrations. The research hypothesis stating that if *Drosophila melanogaster* were exposed to various concentrations of azadirachtin, the number of eggs produced would diminish with the increasing presence of the chemical, was not supported by the data. These results suggest that the reproduction rate of fruit flies is not noticeably decreased with such a low-level present in their environment; however, further research adjusting the variables outlined in this study may yield valuable information in how azadirachtin impacts the reproductive system of *Drosophila* and, potentially, that of humans.

Honorable Menion

Bhatti Daniyal, Mills E. Godwin High School

The Effect of Centella asiatica Extract on Stem Cell Regeneration Modeled by Dugesia dorotocephala

The purpose of this experiment was to find out the effect of *Centella asiatica* extract on stem cell regeneration using *Dugesia dorotocephala* as a model. Normally, when a patient experiences costly dermal wounds, stem cells are the first to rush in and heal the wound through differentiation. Researching herbal medicine could lower treatment costs and effectively heal dermal wounds. *C. asiatica* extract was applied in amounts of 1, 2, and 3 mL, with 0 mL being the control.

The *Dugesia dorotocephala* were cut in half and given the extract for 4 days before measuring their regeneration. A hypothesis was formulated that if 3 mL of the extract was given, then there would be the greatest amount of stem cell regeneration for that group. The results displayed that the control group had the most stem cell regeneration, while the experimental groups had 0% average regeneration because the planaria had decomposed. Six t-tests showed that the data were not statistically significant ($p > 0.05$). Thus, the null hypothesis failed to be rejected, and the research hypothesis was not supported. The way the results turned out is presumed to be due to the *C. asiatica* extract, as it contained phenoxyethanol. The experimental groups lost their anatomical structures because of the phenoxyethanol's toxicity, resulting in death. Since the control group was not treated, no death occurred while normal regeneration continued. The study conducted could lead to additional research ideas regarding the dangers of phenoxyethanol and herbal medicine on stem cells.

Bowman Lilly, Southwest Virginia Governor's School
The Birth Weight of Lambs When the Ewe is Fed More Protein

This experiment examines the effect that protein has on the birthweight of the lamb when the ewe is fed a higher amount of protein for the last thirty days of the pregnancy. A group of 40 ewes was split into two groups of 20. However, the first 20 lambs in each group were weighed, resulting in only 25 ewes being used in this research. After the groups were made, one group received a higher protein feed regime that contained 18% protein. The other group received a lower-protein regimen containing 15% protein. Both of these feed regimes were fed to the groups for 30 days before their due date. Results indicated that there was no significant difference between the mean weights of the two groups. These results showed that there was not enough evidence to state that the amount of protein a ewe consumes before her due date directly corresponds to the birth weight of the lamb born. This result could help smaller family-owned sheep operations by allowing them to recognize if they need to change feeds to help with birth weights and mortality rates among their lambs

Kwong Isaac, Central Virginia Governor's School for Science and Technology
The Effect of Sound Based Conditioning Trials on the Behavioral Response of Orthoporus texicolens

The purpose of this research was to determine the effect sound based conditioning trials have on the behavioral response of *Orthoporus texicolens (millipedes)*. The hypothesis was that if *Orthoporus texicolens* are conditioned for 4 weeks with a 300 Hz tone paired with a reward, then, when the tone is later presented without the reward, the millipedes will approach the location previously associated with the reward. The researcher had an experimental group that underwent 3 phases: The Food Phase (exposed to only food), The Sound-Food Phase (exposed to sound and food), and The Sound Phase (exposed to only sound), with one control group exposed to only food and another exposed to only sound. The experiment was conducted over 16 days, with one trial per day. The researcher ran a one-way ANOVA Test for the number of millipedes that made it to the reward, and a Chi-square Goodness of Fit Test on the means of the time the *Orthoporus texicolens* reached the reward across the groups. The results from the ANOVA Test produced p-values that are larger than the alpha level of .05, with the p-value of .10 being the lowest among all. The results from the Chi-square Goodness of Fit Test also produced p-values that are larger than the alpha level of .05, with the p-value of .127 being the lowest among all. The result suggests that although millipedes have a level of intelligence, they do not have the ability to associate sound with food.

Buhler Alex, Mills E. Godwin High School
The Effect of Caffeine and Social Environment on Drosophila melanogaster Longevity

This experiment was conducted to find the effects of different social environments and caffeine exposure on *Drosophila melanogaster. Drosophila melanogaster* was placed into isolated or single and groups of three social environments with half of each being exposed to caffeine and the other not exposed to caffeine. The length of time they survived after the start of the experiment was recorded in longevity. It was hypothesized that if a single *Drosophila melanogaster* organism is isolated during

caffeine exposure, then its longevity will decrease compared to grouped flies or the experimental groups without exposure to caffeine. It was found that the isolated or single environment with caffeine exposure had the largest impact on longevity compared to the three other experimental groups. A t-test was performed on the data that showed that the data was significant for each level. The results of the experiment supported the research hypothesis that an isolated environment with caffeine exposure would lead to the shortest longevity. The reason for these results is that fruit flies are social organisms that survive better in social environments and without caffeine exposure. To continue research on this, one could investigate the difference in longevity in different sizes of social groups like 15 or 20 organisms.

Simon Sophia, Clover Hill High School
The Effect of Using Vinegar vs. Fly Traps on the Number of Fruit Flies Caught, Over Time

Fruit fly infestations around the world attack crops and produce, hurting farming revenues, profits, and international markets. As the dysfunction of the agricultural community accumulates, the need to put systems in place to effectively kill these insects are progressively crucial. Previous studies' research details apple cider vinegar and fly traps separately, failing to highlight the comparison between the two substances that generally attract fruit flies. In this experiment, 50 wingless fruit flies were placed in a vial which was in a container and were left to choose between apple cider vinegar and a blue UV light fly trap. The mean for the number of fruit flies caught in water (5.60) was significantly lower compared to the number of fruit flies caught in the UV fly trap (18.83). The mean for the number of fruit flies caught in vinegar (29.0) was significantly higher than the fruit flies caught in the UV fly trap (5.33). This report presents results from experimentation which conveys that most fruit flies are attracted to vinegar. Conversely, UV light is attractive to the fruit flies, but less than the vinegar. Essentially, it is appropriate to speculate that fruit flies are more attracted to the smell of acetic acid than the sight of blue UV light due to the enhanced levels of attraction fruit flies experience. These findings explain why vinegar is most commonly used in households to exterminate fruit flies. Homemade vinegar fly traps are inexpensive and cost-effective in comparison to purchased fly traps. With these new findings, farmers are better equipped to take on fruit fly infestations and save crops. The reduction of the number of fruit flies around the world will help feed the growing demand of food for Earth's increasing population.

VJAS Delegate to American Junior Academy of Science

Ridhi Gutta, Academies of Loudoun
Combatting Lassa Fever: Investigating Pathogenisis and Constructing a Preliminary Vaccine Candidate

Abstract
Lassa Fever is a hemorrhagic fever caused by Lassa virus (LASV) with an estimated >100,000 human infections per year in Western Africa. Currently, there are no approved vaccines or therapeutics against LASV. Additionally, the development process for LASV vaccines and treatments is inhibited by the necessity for high containment laboratory space and funding neglect. This research aims to characterize the first full LASV ribonucleoprotein (RNP) complex, predict potential immunogenic epitopes *in silico*, and validate those peptides *in vitro*. Here, we constructed the first full RNP complex for LASV, validating plausibility through Ramachandran analysis and molecular dynamics simulations. We also identified several T cell and B cell epitopes using advanced bioinformatic analysis. Several predicted immunogenic peptides were confirmed to be antigenic *in vitro.* Furthermore, an analysis of the sera/survival data of guinea pigs vaccinated with LASV glycoprotein DNA produced no neutralizing antibody titer, however, were protected from lethal challenge with LASV, suggesting that T-cell immunity and/or non-neutralizing antibody responses are the true drivers of successful LASV vaccination and protection. These peptides are promising candidates for future LASV vaccine construction.

1. Introduction

Lassa virus (LASV), first described in 1970, causes over 100,000 infections annually in West Africa. LASV is hosted by murid rodents. Around 20% of LASV cases progress to LF. By a conservative estimate, 16.5% of LF cases become fatal, although the number can climb up to 20% (Simons, 2023). Current LF treatment is limited to supportive care and use of the antiviral ribavirin; despite the fact that ribavirin's efficacy and safety are doubted, there are currently no approved vaccines for LF. (Cheng et al., 2022). Notably, the World Health Organization (WHO) added LF to their list of priority diseases for which to develop safe and effective vaccines (World Health Organization, 2018).

LASV is of the virus family Arenaviridae, genera Mammarenaviridae, order Bunyavirales, and phylum Negarnaviricota. A negative-stranded RNA virus, its genome comprises small (S) and Large (L) segments. It uses an ambisense strategy to encode four proteins: Nucleoprotein (NP), Glycoprotein precursor (GPC or GP), RNA dependent RNA polymerase (L), and Zinc-binding protein (Z). The LASV ribonucleoprotein complex (RNP) consists of the L protein, NP protein, and viral RNA with the Z protein scaffolded onto the complex to facilitate viral budding. The RNP protects the viral RNA from recognition by cellular pattern recognition receptors and has been implicated in viral replication and transcription. While the basic structure of the RNP is known to be a dynamic double helix similar to that of other negative strand RNA viruses, a full 3D model of LF's RNP has never been constructed, obscuring the molecular mechanisms by which the RNP inhibits the host immune system and interacts with host proteins (Pattis & May, 2020). Absent knowledge of the RNP structure and function, developing effective drugs and vaccines becomes significantly more difficult, obstructing treatment for those who need it.

However, even with enhanced knowledge of LF's genome, identifying and developing effective therapeutic measures has proven to be extremely expensive and time

consuming. The total cost of vaccine development can range from $200M to $500M and can take over 15 years (Plotkin et al., 2017). In the past decade, numerous immunoinformatic in silico vaccine candidates have been developed and validated in vitro, substantially reducing trial and error related inefficiency.
Interestingly, T-cell responses have been implicated in the disease process of LF, with severe LF being associated with T-cell activation of unrelated antigenicity and poor LASV specific T-cell responses. Furthermore, compelling evidence supports that T-cell activation plays an important role in protection from LASV infection and development of LF. T-cell humanized mice are protected from LASV infection after vaccination with Mopeia virus and protection is primarily driven by the T-cell response (Flatz et al., 2010). Unlike previous papers focusing solely on immunoinformatic vaccine development for LASV, this manuscript performs a holistic investigation. We propose a structure of the LASV RNP and utilize an exploratory antigen discovery approach to fuel epitope-driven vaccine development, extending virus characterization and therapeutic identification strategies.

2. Materials and Methods

2.1 Sequence Acquisition

The sequences used in the model construction and characterization were acquired from the NCBI protein sequence database through the NCBI Virus portal. The reference sequences for the 3 LASV RNP proteins (L, Z, and NP) were downloaded. The GP reference sequence was downloaded as well for further in silico analysis. All sequences utilized were from the Josiah strain, which is the prototypical strain of LASV used in the laboratory.

2.2 RNP Structure Generation and Characterization

The current RNP structure, while significant to pathogenesis, is unelucidated. To generate the trimeric complex, AlphaFold, a state-of-the-art deep-learning molecular modeling program, was used. The RNP structure is known to shift conformationally with and without the presence of viral RNA. However, because AlphaFold is computationally expensive for amino acids sequences over 5000 characters, viral RNA was omitted in the analysis. While combinatorial protein docking is typically necessary to model complexes, AlphaFold3 has the unique ability to find the optimal complex structure without intensive numeric computation. The AlphaFold model was evaluated for quality using the UCLA PROCHECK server to map model quality. The structure's characteristics were analyzed using molecular dynamics via NeuroSnap SPRINT. The AMBER99SB-ILDN force field was used at a temperature of 300 degrees celsius in a cubic solvent box. Normal mode analysis (NMA) was performed through iMODS, a server that maps the coordinated movement of internal coordinates and torsional angles of the RNP complex. This

helps assess protein stability and predict the complex's natural movements, considering the B-factors, covariance, deformability, and eigenvalues.

2.3 In Silico Peptide Prediction

Due to their favorable location within the virus and antigenic properties, GP and NP were utilized in the in-silico peptide screening analysis. All LASV vaccine studies to date have focused on GP and NP so this approach concurs with literature.
In silico epitopes were predicted both for T cell and B cell response. There exist two main types of T cells: cytotoxic (CD8+) and helper (CD4+). Both types of T cells are important in ensuring a holistic immune response. These cell types are abbreviated as CTL and HTL respectively.
To screen CTL epitopes, the NetMHCPan 4.1 platform was used at the default percentile rank thresholds of 1 for strong binders and 5 for weak binders. To screen HTL epitopes, the NetMHCIIPan 4.0 platform was used at the default percentile rank thresholds of 1 for strong binders and 5 for weak binders. BepiPred, an online server that uses a random forest algorithm trained on annotated epitopes from antibody-antigen protein structures, was used to predict LBLs (Clifford et al., 2022).
There were many criteria used to decide which epitopes should be used in the vaccine construct. For CTL epitopes, the antigenicity, immunogenicity, allergenicity, solubility, toxicity, and MHC I binding affinity were evaluated. For HTL epitopes, the antigenicity, allergenicity, solubility, toxicity, IFN-y, and IL-4 inducing capability were evaluated. For B-cell epitopes, the antigenicity and allergenicity were evaluated.
The Vaxijen server predicted the antigenic capacity of CTL, HTL, and B-cell epitopes. The IEDB MHC-I Immunogenicity Module was used to evaluate the immunogenicity of CTL epitopes (Fleri et al., 2017). Epitopes scoring higher than zero were processed for further analysis.
Epitopes that were determined to be both antigenic and immunogenic were further assessed for solubility and toxicity using the CamSol Intrinsic and ToxinPred servers respectively. ToxinPred uses multiple physicochemical properties of a peptide to calculate its toxicity. Epitopes with a solubility higher than 0 and a toxicity of less than 0 were selected for further evaluation.

HTL epitopes satisfying all aforementioned constraints aside from immunogenicity and MHC I binding affinity, which are specific to CTL epitopes, were subjected to allergenicity (CTL as well), IFN-y production, and IL-4 production analysis. Allergenicity was predicted using the AllerTOP v 2.0 server. The IFNepitope server (https://webs.iiitd.edu.in/raghava/ifnepitope/design.php) was used to predict the ability of HTL epitopes to induce IFN-γ production (Dhall et al., 2024). The IL-4pred server (https://webs.iiitd.edu.in/raghava/il4pred/predict.php) was used to predict the ability of HTL epitopes to induce IL-4 production (Dhanda et al., 2013).

2.4 T-Cell Activation Assay

In order to validate the results from the in silico screen, a series of 45mer peptides overlapping by 15 amino acids on either side spanning the entire sequence of LASV NP and GPC were ordered from Biomatik and used to identify epitopes that induce T-cell activity in vitro.
Human peripheral blood mononuclear cells (PBMCs) acquired from American Tissue Culture Collection (ATCC) were thawed in a 37-degree water bath and deposited in 10mL of complete RPMI media. Cells were washed, DNase treated (to remove clumping) and resuspended in growth media (X-VIVO 15). Cells were seeded at a

concentration of 1e5 cells per well in 96-well plates. Cells were acclimated to the growth media and then incubated with differentiation media containing GM-CSF, Flt3-L, and IL-4 to induce differentiation into the various constituents of the immune response including macrophages and dendritic cells. The cells were incubated for 7 days at 37C + 5% CO2 to complete differentiation. Following differentiation, each peptide was added to its respective well in a 2μM concentration as per the setup in Fig. 2. Additionally, a subset of cells were left unstimulated as a negative control as well as to be used as a positive control in a later step. That untouched segment of cells was later exposed to PMA/Ionomycin to globally activate the T cells as a positive control. Peptides were suspended in growth media containing adjuvants to enhance the immune response. The cells were incubated for 2 weeks with media changes every 2-3 days. Following priming, cells were stimulated by combining each replicate of each peptide into one tube and centrifuged at 400G. Cells were resuspended in growth media plus T-cell stimulating cytokines and pools of peptides spanning either the GPC or NP proteins of LASV. Cells were incubated overnight and analyzed

with flow cytometry following standard protocols. To maintain safety, all work was performed using a BSL-2 safety hood. Lab coats and gloves were worn. All waste was disposed of in biohazard bins.

2.5 B-Cell activating Epitope Detection

To evaluate humoral immune response to the synthetic peptides, an ELISA was performed. Each peptide described in the T-cell activation experiment was diluted in PBS and added to individual wells of a 96-well plate in duplicate and incubated overnight to allow the peptides to fully coat the wells.. Following the coating, the plate was washed and blocked with 0.5% BSA for 30 minutes. Primary antibody (hyperimmune mouse ascites fluid (GP) or anti-NP rabbit polyclonal antibody (NP)) was then diluted to the desired concentration (~1:150) in blocking buffer and added to the wells. Plates were incubated for 1 hour at room temperature with gentle rocking. Following primary antibody incubation, wells were washed 3 times with PBS + 0.1% Tween. HRP conjugated secondary antibody (anti-mouse (GP) or anti-rabbit (NP)) was diluted to the desired concentration (~1:10,000) in PBS + 0.1% tween and incubated for 1 hour at room temperature with gentle rocking. Following incubation, cells were washed 3 times with PBS + 0.1% Tween and 100μL of TMB substrate was added to each well and incubated for
~15 minutes. Once the blue color was observable, 100μL of TMB Stop Solution was added to each well. Absorbance was read at 450nm on a plate reader. To maintain safety, gloves,
close-toed shoes, and lab coats were worn to prevent skin-liquid contact.

2.6 Plaque Reduction Neutralization Test (PRNT) Data Analysis

A LASV pseudovirion system was used with sera from guinea pigs that were vaccinated with LASV GPC DNA obtained from a study at USAMRIID. As a qualifying remark, the GPC vaccinations and live animal work were conducted independent of this research at a separate location. The guinea pig study itself was not conducted as a part of this paper. However, the GPC vaccine studied had significant overlap with the GP synthetic

peptides. Thus, it was determined that performing a PRNT with the vaccinated guinea pig sera (BSL-2) would provide some insight into the neutralizing antibody titer that the identified GPC peptides may generate.

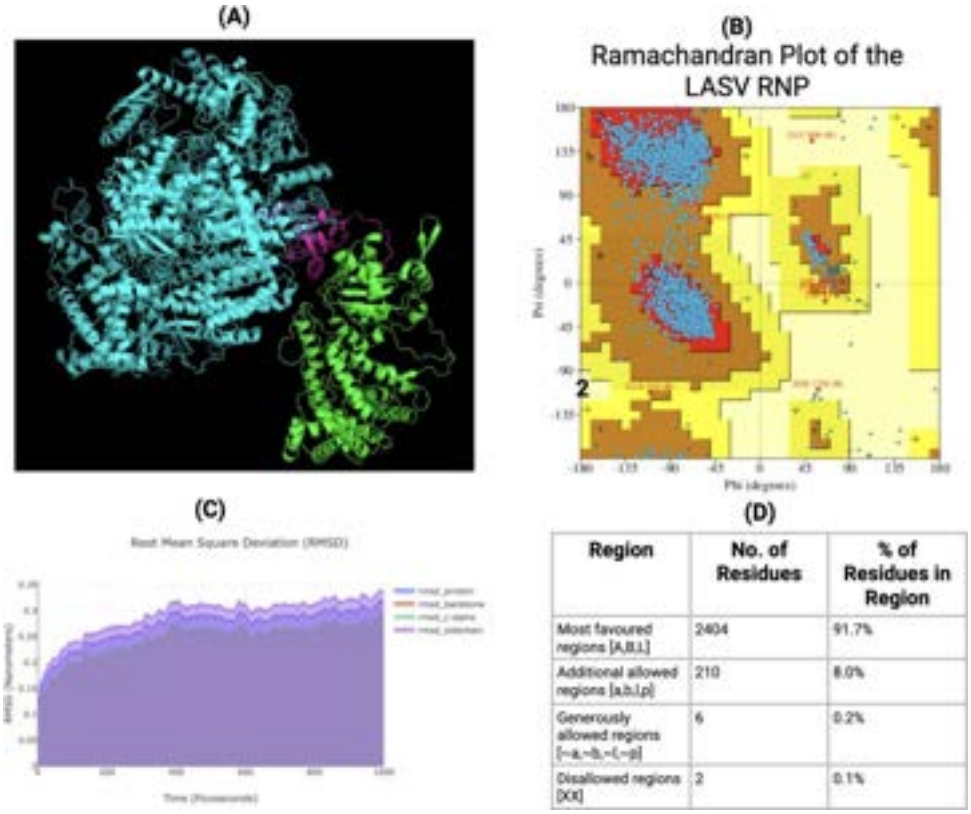
The survival data of the aforementioned study was independently analyzed to determine the potential relationship between the GPC peptides studied here and animal survivability. The survival data show that 6 of 8 guinea pigs vaccinated with LASV GPC DNA survived a lethal LASV challenge compared to 1 unvaccinated control animal. Blood collected prior to the challenge was processed and serum was collected. This serum was analyzed for the presence of neutralizing antibodies against LASV using a pseudovirion system. Prior to the experiment, a confluent monolayer of Vero cells for the pseudovirion was prepared in a separate cell culture plate. To conduct the PRNT, the sera were centrifuged at 1,000-2,000xG for 10-15 minutes. The two sera groups were control vaccine (empty DNA plasmid) and LASV GPC DNA plasmid. The pseudovirion was cultivated in the Vero cell culture until a sufficient pseudovirion titer was achieved. Then, a working pseudovirion stock was prepared by diluting the virus in a cell culture medium to 100 pfu/mL. A series of serial dilutions of the serum was prepared in a 96-well microtiter plate. The dilutions started at 1:4 and continued in a Log2 pattern. Duplicate wells were prepared for each dilution. An equal volume of the working stock was added to the diluted serum in each well of the microtiter plate. The plates were then mixed gently and incubated for 1 hour. This allows the neutralizing antibodies in the serum to interact with the virus. The pseudo virion-serum mixture was removed from the incubation step and transferred onto the cell monolayer in the cell culture plate. The plate was then incubated to allow the pseudovirion to infect the cells. After removing the cell culture medium, 300uL of inoculum was added (enough to cover the plate). The infected cells were covered with agarose overlay containing nutrients. Subsequent incubation created an environment to facilitate plaque formation. Following the incubation period, the cells were stained with crystal violet, and the number of visible plaques was counted. The plaque reduction percentage for each serum dilution in comparison to control without serum was calculated. A neutralizing antibody titer was generated based on the highest serum dilution that yields a 50% reduction in plaque formation. Safety measures were taken as described in sections 2.4 and 2.5.

3. Results

3.1 Protein Model Analysis

The predicted template modelling (PTM) score generated by AlphaFold was 0.65. A pTM score above 0.5 means the overall predicted fold for the complex might be similar to the true structure. Thus, the predicted structure has a high likelihood of alignment with the true

LASV RNP structure. It should be noted, however, that the interface predicted template modelling (iPTM) score was 0.41. The iPTM score evaluates the accuracy of the predicted relative subunits of a complex. 0.41 is on the lower end, suggesting that, while the overall structure is likely accurate, further refinement and wet-lab structural insight is required to determine the exact position of each residue within the complex. Nonetheless, this structure can be used as a starting point for future investigations.



Region	No. of Residues	% of Residues in Region
Most favoured regions [A,B,L]	2404	91.7%
Additional allowed regions [a,b,l,p]	210	8.0%
Generously allowed regions [~a,~b,~l,~p]	6	0.2%
Disallowed regions [XX]	2	0.1%

Figure 1: (A) PyMol visualization of the constructed RNP complex (blue = L protein; pink = Z protein; green = NP protein). (B) Ramachandran plot of Phi (degrees) vs Psi (degrees) of the RNP complex with 91.7% of residues in the most favored regions. (C) Root Mean Square Deviation (RMSD) of the RNP complex in an AMBER99SB-ILDN force field (<0.35 nm). (D) Table of Ramachandran plot values showing residue breakdown by region (>90% most favored)

Molecular dynamics (MD) and Ramachandran analysis of the generated RNP structure reveal the plausibility of the structure by describing the combinations of Φ and Ψ dihedral angles

that are or are not permitted in a peptide backbone (Figure 4B). A Ramachandran score of >90% of residues in the most favorable area generally indicates the model is of high quality and minimal steric interference; for this model, 91.7% of residues were found to be in the most favoured regions, corroborating the favorable PTM value (Figure 4D). This indicates that the majority of the structure is conformationally stable.

In MD the simulation, RMSD was analyzed; RMSD is the measurement of the average distance between the backbone atoms of the protein. The RMSD plots predicted the highest deviations to occur at 400 and 1000 picoseconds (Figure 4C). While RMSD increased significantly, it stabilized at around 500 picoseconds, remaining relatively constant until the end of the simulation. The net change in RMSD was 0.2 nanometers, which translates to around 2 angstroms. This is a relatively small change, indicating that the model is conformationally stable.

3.2 In Silico Peptides

The raw in silico peptide predictions were compiled by computationally predicted parameters and sorted according to pre-determined in vitro viability screening criteria. All epitopes were first filtered by binding affinity for MHC-I and MHC-II alleles. The cutoff for antigenicity was 0.4 and above. The cutoff for immunogenicity was 0 and above. The cutoff for solubility was 1 and above. The cutoff for toxicity was 0 and below. Additionally, the peptides must have been non-allergenic. HTL epitopes were also required to be IFN-y inducing and IL-4 inducing.

3.3 T Cell Activation Assay Flow Cytometry Results

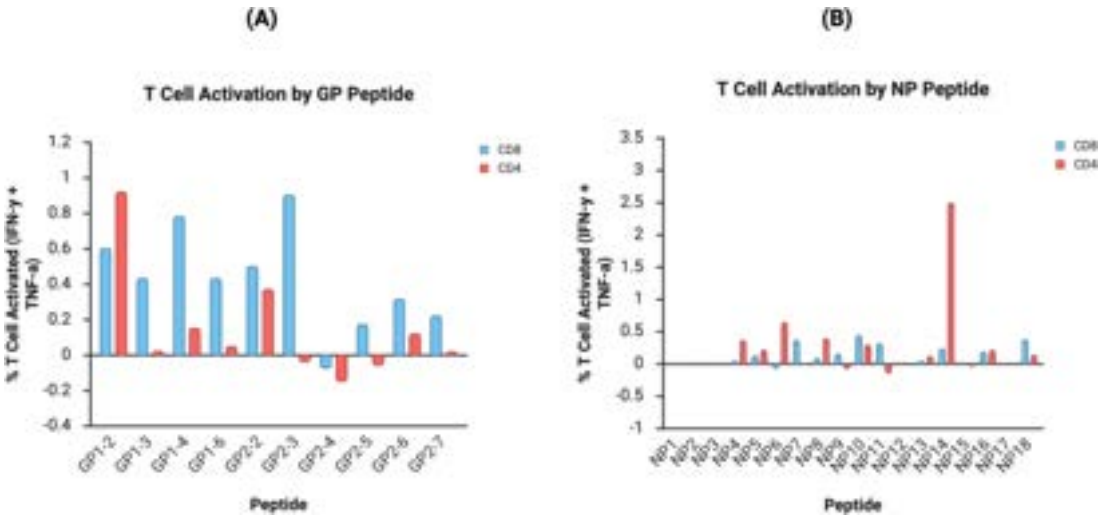
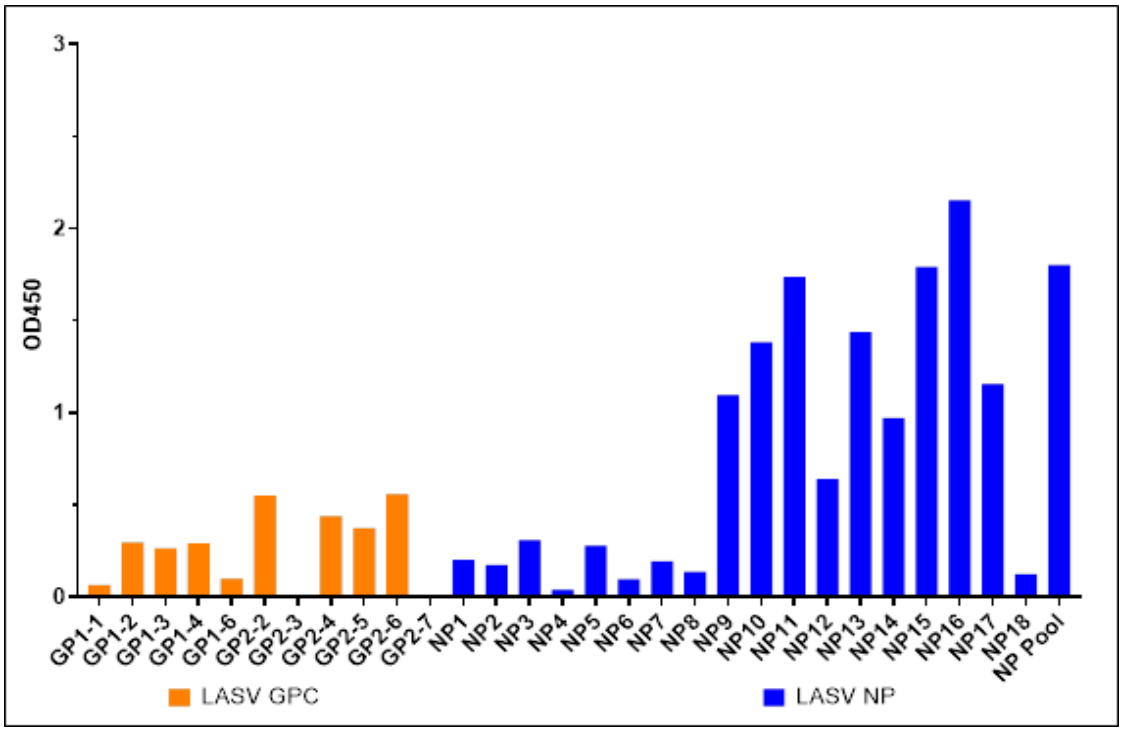


Figure 2. CD8+ and CD4+ cell activation for each GP (A) and NP (B) peptide. The y-axis represents the percent of cells secreting either TNF-a and/or IFN-y.

Human peripheral blood mononuclear cells were differentiated, primed, and stimulated with 45mer peptides spanning the entire LASV GPC and NP proteins. Cell samples were primed with individual peptides for 2 weeks and then stimulated with peptide pools from each protein. Peptides near the c-terminal region of the GP1 protein were the most CD8 stimulating, however one peptide near the n-terminal of GP2 as well as in the middle of the NP protein were also CD8 activating. Peptides near the c-terminal of NP



were CD4 activating, whereas few peptides from GPC were CD4 stimulatory. These results are consistent with peptides found in silico.

The predicted GP CTL epitopes had significant overlap with GP1-2, GP1-4, GP1-6, GP2-3, and GP2-5. The GP HTL in silico predictions were slightly less accurate. Several epitopes overlapped with GP1-6, which is CD8 positive but not CD4 positive. The only other predicted epitope overlapped with GP2-4, which is not CD8 or CD4 positive.

The NP CTL epitopes displayed a similar trend. There was overlap with in vitro epitopes NP7, and NP11, which were positive for CD8 activation. The immunoinformatics pipeline also predicted that the peptides within NP8, NP13, and NP17 would be CD8 activating. While none of these peptides were CD8+ activating, NP8 and NP13 were CD4 activating. The HTL epitopes overlapped with NP4, NP11, and NP13. NP4 and NP13 were associated with CD4+ activation in vitro while NP11 was not, indicating that the immunoinformatics approach was moderately successful.

3.4 B Cell Stimulating Peptides

Figure 3: OD450 (absorbance at wavelength 450 nm) for in silico identified GPC/NP peptides.

Next, we mapped peptides to antibody populations from vaccinated animals. Hyper immune mouse ascites fluid from a mouse that was vaccinated with LASV GPC in the presence of adjuvants was obtained from BEI resources. Additionally, a polyclonal antibody targeting LASV NP protein that was produced in a LASV NP vaccinated rabbit was obtained from ThermoFisher. These reagents are commercially available for

purchase and were not made for the specific purpose of this study. Plates were coated with the indicated peptides and the hyper immune mouse ascites fluid (GPC) or the polyclonal NP antibody (NP) was used to detect each peptide. Positive results indicate the presence of antibodies that recognize the indicated peptide.
Our results show that the c-terminus of the NP protein is significantly more antigenic than the n-terminal region of the same protein. GPC antigenicity appears to be more global across the protein with a few exceptions.
Between all three experiments, it was found that GP1-2 produced both B cell and CD8+ response. NP11 and GP2-6 produced both CD8+ and CD4+ responses. NP14 produced both

CD4+ and B cell response. GP2-2 and NP10 produced all three responses. These results were somewhat aligned with the in silico results.

3.5 PRNT Results

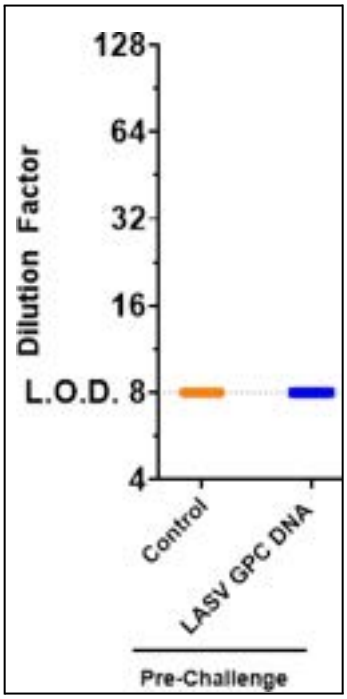


Figure 4: Minimum dilution factors to reach 50% pseudovirion neutralization for 5 guinea pig sera samples pre- and post-challenge. The guinea pig sera GPC vaccination across the study term was performed entirely independent of this paper. We simply used the guinea pig sera to perform a PRNT to quantify how immunogenic the GPC peptides may be in vivo due to the high overlap between the studied vaccine and the synthetic peptides.

Guinea pig sera samples were taken from a GPC DNA vaccine study performed independent of this research in which the vaccine had significant overlap with the predicted GPC peptides used in the T-cell and B-cell assays. It is important to note that

all work on animal samples was done elsewhere independent of this study. We simply analyzed sera samples and survival data from the study. Analysis revealed that, while the vaccine was effective in protecting the animals (p=0.04 by the log rank test), no neutralizing antibodies were seen until
post-challenge. This suggests that the primary mechanism of protection is non-neutralizing

response and/or the T cell response, providing some insight into the immunogenic capability of GPC as well as the mechanism of protection induced.

4. Discussion and Conclusions

Our computational analysis was able to generate and characterize a full structure of the RNP. Ramachandran analysis (most favorable residues > 90%) confirms that the generated structure is high-quality with minimal steric hindrance. MD simulations confirm that the structure moves ~2 angstroms, indicating stability and minimal deviation from its original position. Normal mode analysis further confirms structural stability, providing insight at the residue level.

The in-silico analysis was able to identify upwards of 50 potential CTL, HTL, and B cell peptides although many had significant overlap. These peptides all had optimal antigenicity, immunogenicity, solubility, non-toxicity, IFN-y producibility, and IL-4 procurability results. This pipeline could be used in the future to screen epitopes for any virus. The extended versions of these peptides were chemically synthesized and tested with T cells and B cells.

Flow cytometry analysis of T cell response reveals that several peptides activated both CD8+ and CD4+ T cells. Among the most significant were GP2-2 and NP10, which were later determined to elicit CD4+, CD8+, and B cell immune responses. These peptides could be further investigated in vitro or in vivo as potential peptide vaccine candidates for LASV treatment. The PRNT results were also significant; while the tested sera was not in perfect alignment with the GPC epitopes used in the other in vitro assays, the results suggest that non-neutralizing antibody response and T cell response are more important in protecting organisms from lethal infection than the usual gold standard, neutralizing antibodies. This suggests that it is the virus and not vaccination causing neutralizing antibodies to be produced. Further study needs to be performed to determine if the production of neutralizing antibodies post infection but not post vaccination is important to protection and/or pathogenesis. Additionally, determination of the viral components that induce neutralizing antibody production could help drive further vaccine design.

The results of this study provide a significant foundation for future study of LASV. The RNP structure can be further validated in vitro and studied to elucidate novel mechanisms of pathogenesis. The in silico and in vitro identified peptides could be investigated in the future as potential vaccine candidates for LASV.

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VJAS Alternate Delegates to AJAS

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Curcumin suppresses HNSCC tumorigenesis through directly targeting FOSL1/JUN

Abstract

Natural products and affordable herbal medications have emerged as promising alternatives for cancer therapy, particularly for patients with limited access to standard treatments. Among these, curcumin, the bioactive polyphenol from *Curcuma longa* (turmeric), has shown broad anti-cancer potential. However, its molecular mechanism remains poorly defined, especially for head and neck squamous cell carcinoma (HNSCC). Here, we identify curcumin as a potent inhibitor of HNSCC tumorigenesis and explore its underlying mechanism. Comparative analyses of three anti-cancer natural products, including curcumin, gingerol, and allicin, revealed that only curcumin robustly inhibited HNSCC cell proliferation, invasion, and cancer stem cell self-renewal, with potency comparable to or superior to cisplatin. Transcriptomic and Gene Set Enrichment Analyses demonstrated that curcumin significantly suppressed FOSL1/AP-1 signaling, a well-known key oncogenic signaling that promotes malignant progression of HNSCC. Biophysical and biochemical assays showed that curcumin directly binds to the FOSL1/JUN heterodimer (Kd ≈ 10 μM), disrupting its DNA-binding activity. In agree with this finding, chromatin immunoprecipitation confirmed that curcumin inhibited FOSL1/JUN recruitment to the promoter of cancer stem cell marker gene *BMI1*, as well as super-enhancer–associated oncogenic loci such as *MET*, *EGFR* and *TP63*. At last, curcumin treatment profoundly suppressed HNSCC tumor growth in xenograft model and exhibited superior efficacy compared with the FOSL1/AP-1 inhibitor T-5224, without apparent toxicity. Collectively, our findings identify FOSL1/JUN complex as a direct molecular target of curcumin and uncover a novel mechanism by which this accessible natural product suppresses HNSCC tumorigenesis, supporting its potential as an affordable and safe therapeutic option for cancer treatment.

Introduction

Cancer remains one of the leading causes of mortality worldwide(Siegel et al., 2025). Despite significant advances that have been made in treatment approaches, including chemotherapy, targeted therapy, radiotherapy, and immunotherapy, global cancer incidence and mortality rates remain high. Many patients continue to face limited access to effective treatments due to high costs and insufficient healthcare infrastructure(Guo et al., 2023; Ocran Mattila et al., 2021).

In recent years, there has been growing interest in exploring over-the-counter herbal medicines and the natural products derived from them for potential therapeutic applications in human diseases, including cancer(Asiimwe et al., 2021; Cui et al., 2025; Donkor et al., 2022; Wu et al., 2025). These natural supplements, available as capsules, tablets, powders, or liquid extracts, are often taken as dietary complements to provide bioactive compounds believed to promote health and combat disease. Among the most affordable and accessible natural products that have demonstrated anti-cancer activity are curcumin, gingerol, and allicin, the active ingredients of turmeric, ginger, and garlic, respectively(Abdull Rahim et al., 2024; Bhuker et al., 2024; Gutsche et al., 2025). Research on these natural products holds tremendous promise for

benefiting millions of cancer patients, especially those without access to advanced medical treatments.

HNSCC accounts for 90% of all head and neck cancer cases and is the 6th leading cancer worldwide. The 5-year survival rate of patients with HNSCC is around 68% in the United States, especially the human papillomavirus negative (HPV [-]) subtype, which has a 5-year survival rate around 50%, due to a lack of effective therapies(Johnson et al., 2020). To explore affordable therapeutic options for HNSCC, we evaluated the anti-cancer potential of curcumin, gingerol, and allicin in suppressing HNSCC cell growth, comparing them with cisplatin, a commonly used chemotherapeutic drug for HNSCC. Remarkably, among the natural compounds tested, curcumin was the only one that exhibited strong anti-tumor activity, demonstrating comparable potency to cisplatin in inhibiting HNSCC cell proliferation.

Curcumin is a natural polyphenol derived from *Curcuma longa* (turmeric), a plant native to Southeast Asia cultivated for its rhizomes. Among more than 8,000 identified polyphenols, curcumin stands out for its long history of use in traditional medicine and its wide-ranging biological effects. Extensive studies have demonstrated that curcumin possesses anti-inflammatory, antioxidant, antimicrobial, and anti-carcinogenic properties(Aggarwal et al., 2003; El-Saadony et al., 2022). These effects are mediated through its ability to regulate diverse cellular processes, including gene transcription, post-translational modifications, and enzymatic activity(Tomeh et al., 2019). Moreover, curcumin has been shown to inhibit the proliferation and survival of various cancer cell types by suppressing oncogenic signaling pathways and reducing the expression of oncogenic proteins(Kim et al., 2014; Tomeh et al., 2019; Vallee et al., 2019). However, the molecular mechanisms by which curcumin inhibits cancer cell growth, particularly in HNSCC, are not fully understood. A comprehensive understanding of how curcumin suppresses HNSCC tumorigenesis could provide compelling evidence for its use as a complementary component in cancer therapy. Such insights may also facilitate the development of more effective curcumin-derived therapies, providing affordable treatment options for patients in resource-limited regions.

In this study, we investigated the molecular mechanisms by which curcumin suppresses HNSCC tumorigenesis. We demonstrated that curcumin directly binds to the FOSL1/JUN transcriptional complex, thereby inhibiting its recruitment to oncogenic target genes, particularly those associated with super-enhancers. Furthermore, HNSCC xenograft model confirmed that curcumin profoundly suppresses HNSCC tumorigenesis and exhibits superior efficacy compared with the known FOSL1 inhibitor, T-5224(Aikawa et al., 2008; Zaman et al., 2024). Collectively, our findings uncover a novel mechanism by which curcumin inhibits HNSCC oncogenesis and provide strong preclinical evidence supporting the therapeutic potential of affordable, over-the-counter medications for patients lacking access to standard cancer treatments.

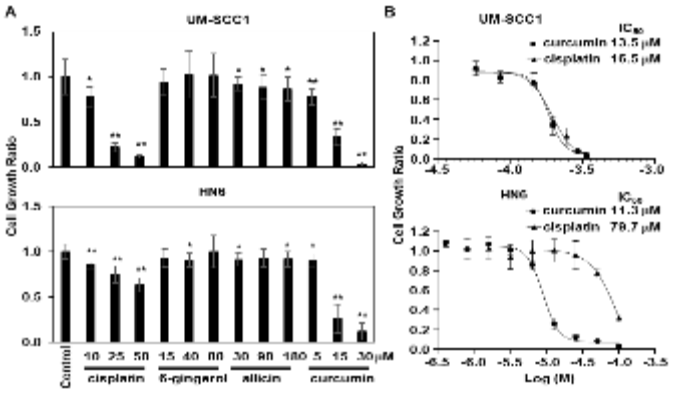

Figure 1. Curcumin was identified to inhibit HNSCC cell proliferation. **(A)** CCK8 assays suggested that curcumin was the only natural product that significantly inhibited HNSCC cell proliferation. * $P<0.05$; ** $P<0.01$; unpaired two-tailed Student's t-Test. **(B)** Comparison of curcumin and cisplatin in suppressing HNSCC cell growth, measured by CCK8 assays. IC_{50} values of the curcumin and cisplatin were listed.

Results

Curcumin was identified to inhibit HNSCC cell proliferation. To evaluate the potential anti-tumor activities of the natural products, UM-SCC1 or HN6 cells were treated with three concentrations of allicin (30, 90, and 180 μM), 6-gingerol (15, 40, and 80 μM), curcumin (5, 15, and 30 μM), as well as the chemotherapeutic drug cisplatin (5, 15, and 50 μM) in parallel. The selected concentrations were based on previously published studies demonstrating inhibitory effects on tumor cell growth under *in vitro* conditions(Maitisha et al., 2021; Marquardt et al., 2015; Tsai et al., 2020; Vallee et al., 2019). The anti-proliferative activities of these compounds against HNSCC cells were examined using the Cell Counting Kit-8 (CCK8) assay 48 hours after treatment. As shown in **Figure 1A**, curcumin was the only natural product that significantly inhibited cell proliferation in a dose-dependent manner, exhibiting comparable potency to cisplatin in UM-SCC1 cells and even greater potency in HN6 cells. To further compare the anti-proliferative effects, we determined the IC_{50} values of curcumin and cisplatin using CCK8 assays. The IC_{50} values for UM-SCC1 cells were 13.5 μM and 16.5 μM for curcumin and cisplatin, respectively, whereas those for HN6 cells were 11.3 μM and 79.3 μM, respectively (**Figure 1B**). These results indicate that curcumin exerts a stronger inhibitory effect on HNSCC cell growth than cisplatin.

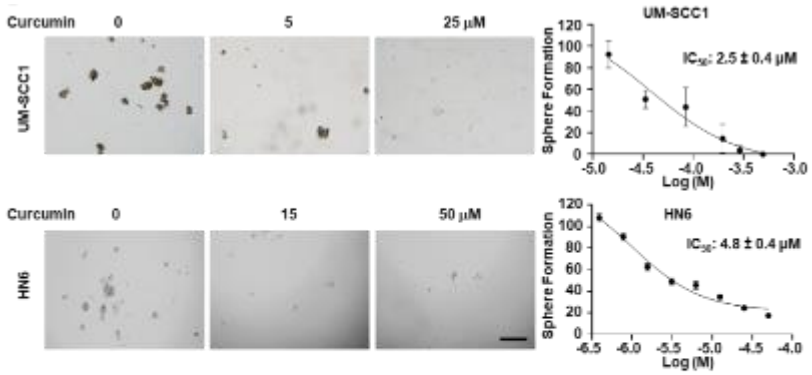

Figure 2. Curcumin inhibited malignant phenotypes of HNSCC cells. Tumor sphere formation assay showed that the self-renewal ability of cancer stem cells of UM-SCC1 and HN6 was inhibited by curcumin. HNSCC cells were treated with increasing concentrations of curcumin as indicated. Scale bar: 200

Curcumin inhibits HNSCC stemness. Cancer stem cells are responsible for maintaining tumor growth and development of chemotherapy resistance(Atashzar et al., 2020; Zhou et al., 2021). Tumor sphere formation assays were performed to investigate whether curcumin can inhibit the self-renewal ability of HNSCC cancer stem cells(Chen et al., 2017; Zhang et al., 2021). UM-SCC1 or HN6 cells were seeded in cancer stem cell media and then treated with increasing concentrations of curcumin for 14 days. The tumor sphere formation ability was significantly suppressed by curcumin (**Figure 2**), indicating that curcumin can strongly inhibit the self-renewal ability of HNSCC cancer stem cells.

Curcumin inhibits FOSL1/AP-1 signaling and cancer stemness gene expression in HNSCC. To explore the molecular mechanisms by which curcumin suppresses HNSCC tumorigenesis, RNA-sequencing was conducted in UM-SCC1 cells after treatment with curcumin, followed by Gene Ontology and Gene Set Enrichment Analysis (GSEA). As shown in **Figure 3A**, several critical signaling pathways were significantly changed by curcumin treatment, including the mitogen-activated protein kinases (MAPK) pathway and several key oncogenic pathways involved in pluripotent stem cell regulation, EGFR inhibitor resistance, and platinum drug resistance. GSEA further revealed that expression of cancer stem cell-associated gene sets was markedly downregulated by curcumin in UM-SCC1 cells (**Figure 3B**).

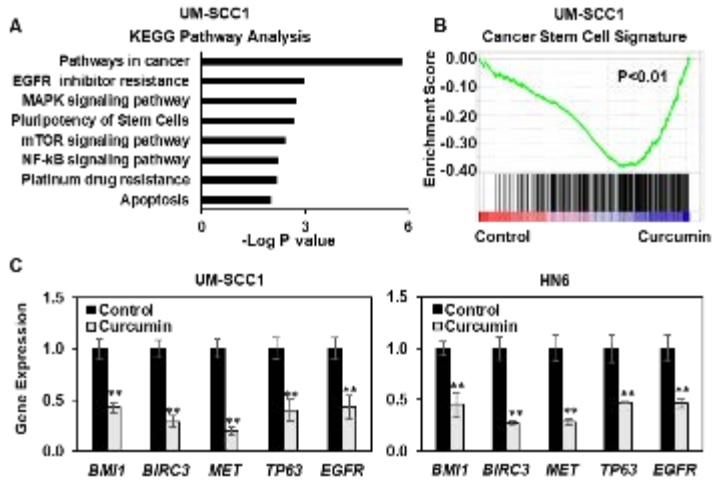

Figure 3. Curcumin inhibited FOSL1/AP-1 target gene expression in HNSCC cells. (A) KEGG Pathway analysis for curcumin in suppressing signaling pathway in UM-SCC1 cells. **(B)** Quantitative comparison of cancer stem cells signature genes downregulated by curcumin in UM-SCC1 cells using GSEA. **(C)** FOSL1 target genes were inhibited by curcumin in HNSCC cells. UM-SCC1 or HN6 cells were treated with increasing concentration of curcumin as indicated for 16 hours. $^{**}P<0.01$; unpaired two-tailed Student's t-Test.

AP-1 is a major downstream effector of both the MAPK and EGFR signaling pathways. Among the AP-1 transcription factors, FOSL1 has been identified as the predominant family member driving HNSCC progression(Zhang et al., 2021). FOSL1 maintains cancer stemness and promotes metastasis by establishing super-enhancers at key cancer stemness and pro-metastatic genes(Wan et al., 2021; Zhang et al., 2021). Elevated FOSL1 expression has also been shown to sustain the functional properties of $Bmi1^{+}$ cancer stem cells and to confer cisplatin resistance in spontaneous mouse models of HNSCC(Chen et al., 2017; Zaman et al., 2024). Based on these bioinformatic findings, we hypothesized that curcumin suppresses HNSCC tumorigenesis by inhibiting FOSL1/AP-1 signaling. To test this hypothesis, RT-qPCR analysis was performed and revealed that curcumin significantly downregulated several key oncogenes, including *TP63*, *BIRC3*, *EGFR*, and *MET* (**Figure 3C**), all of which are directly regulated by FOSL1-super-enhancers and are essential for maintaining the functional properties of HNSCC CSCs(Dong et al., 2021; Zhang et al., 2021). The recent finding indicated that the functional cancer stem cell marker *BMI1* is a direct target of FOSL1 in HNSCC(Zaman et al., 2024). RT-qPCR analysis also showed that *BMI1* expression was significantly suppressed by curcumin treatment (**Figure 3C**).

Curcumin binds directly to the FOSL1/JUN heterodimer to suppress FOSL1/JUN and DNA interaction. FOSL1 belongs to the FOS family of AP-1 transcription factors. The AP-1 complex is a dimer between members of the FOS and JUN families. The AP-1 family transcription factors are potentially involved in tissue-specific

regulation of target genes due to the differential combination of the components of this important transcription factor(Eckert et al., 2013). JUN proteins can form both homo and heterodimers, while FOS proteins do not dimerize with each other and must bind with JUNs to be active(Kouzarides & Ziff, 1988; Nakabeppu et al., 1988). Curcumin has been suggested to suppress AP-1 target gene expression in mouse fibroblast cells(Huang et al., 1991). Additionally, it has also been indicated that curcumin has the ability to suppress FOS/JUN and DNA interaction in an electrophoretic mobility shift assay(Huang et al., 1991), although the molecular mechanism underlying these events was not fully understood. Thus, we hypothesized that curcumin may directly inhibit the recruitment of the FOSL1/JUN complex to its oncogenic target genes, thereby suppressing tumorigenesis in HNSCC. To validate this hypothesis, we first examine whether curcumin can directly bind to FOSL1/JUN heterodimers using biophysical methods. However, we encountered challenges in purifying high-quality

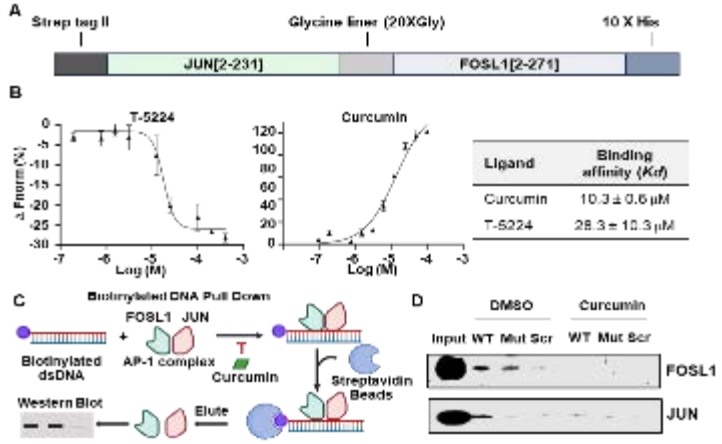

Figure 4. Curcumin directly binds to FOSL1/JUN complex and inhibits its interaction with DNA. (A) The schematic representation of FOSL1:JUN fusion protein purified from bacteria. **(B)** Binding affinities of curcumin and T-5224 to the FOSL1:JUN fusion protein. Dose-response curves of were generated by plotting ΔFnorm values against ligand concentrations. ΔFnorm values represent the ratio of fluorescence intensity after and before the laser-induced temperature change. **(C)** The schematic representation of biotinylated DNA pull down assays. **(D)** Curcumin inhibited the binding of FOSL1/JUN to the dsDNA fragments containing the AP-1 response element.

recombinant JUN protein from E. coli, as most of the expressed JUN protein formed insoluble inclusion bodies. As an alternative approach, we constructed a fusion protein consisting of FOSL1 and JUN linked by a flexible glycine linker(Bakiri et al., 2002), which can be successfully expressed and purified from E. coli (**Figure 4**). As shown in **Figure 4B**, Microscale thermophoresis revealed that curcumin binds to the fusion FOSL1:JUN fusion protein (*Kd*: 10.3 ± 0.6 μM). In comparison, an FOSL1/AP-1 inhibitor, T-5224, which has been widely used in both *in vitro* and *in vivo* investigations display lower binding affinity to FOSL1:JUN (*Kd* = 28.3 ± 10.3 μM).

Next, we investigated whether curcumin can directly suppress FOSL1:JUN fusion protein interacts with DNA. A biotinylated DNA pulldown assays were conducted. This assay was developed to study the FOSL1/JUN complex with DNA interactions(Morris et al., 2022). In brief, the biotinylated AP-1-WT dsDNA fragments or negative control DNA fragments (Scr and Mut) were incubated with cell lysate of UM-SCC1, followed by streptavidin beads pulldown, illustrated in **Figure 4C**. As shown in **Figure 4D**, specific binding of both FOSL1 and JUN to AP-1-WT was dramatically inhibited by curcumin. Taken together, our results strongly suggest that curcumin can directly interact with FOSL1/JUN complex to suppress its interaction with DNA.

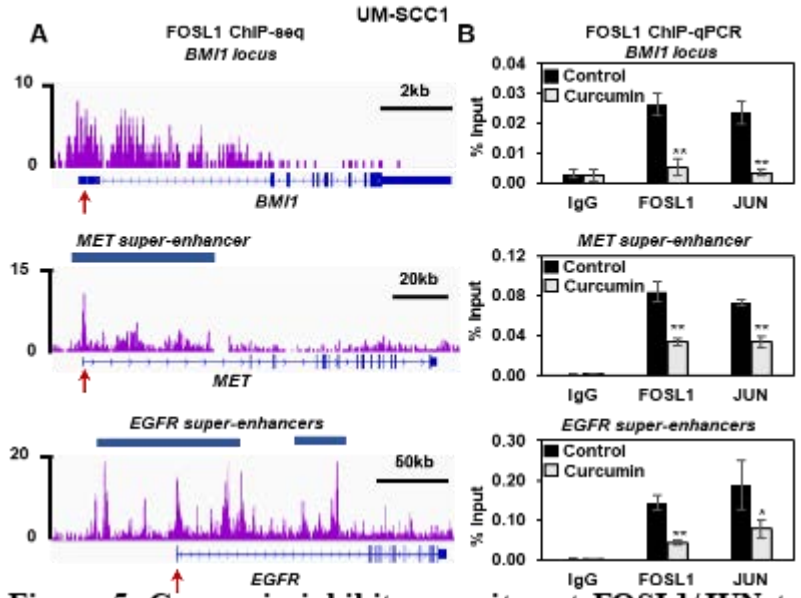

Figure 5. Curcumin inhibits recruitment FOSL1/JUN to oncogenic loci. (A) ChIP-seq analysis showing FOSL1 occupancy at oncogenic loci, including the promoter region of *BMI1*, and super-enhancer regions of *MET* and *EGFR* in UM-SCC1 cells. Arrows indicate the locations of the primers used for ChIP-qPCR. **(B)** ChIP-qPCR showed that curcumin significantly suppressed the recruitment of FOSL1/JUN complex to the *BMI1* promoter and to the super-enhancer regions of *MET* and *EGFR* in UM-SCC1 cells. $^{**}P<0.01$; unpaired two-tailed Student's t-Test.

Curcumin inhibits the recruitment of FOSL1/JUN transcription complex to oncogenic loci in HNSCC. FOSL1 has been reported to promote the malignant progression of HNSCC by establishing super-enhancers at key oncogenes (**Figure 5A**)(Wan et al., 2021; Zhang et al., 2021). The recent investigation further identified the functional cancer stem cell marker *BMI1* as a direct transcriptional target of FOSL1 in HNSCC (Zaman et al., 2024). To determine whether curcumin inhibits the recruitment of FOSL1/JUN to these key oncogenic targets, including those associated with super-enhancers, we performed chromatin immunoprecipitation followed by quantitative PCR (ChIP-qPCR). On note, the ChIP-qPCR primers that specifically for the super-enhancer

loci were selected from the previously published report(Zhang et al., 2021). The ChIP-qPCR analysis revealed that curcumin treatment markedly reduced the binding of both FOSL1 and JUN to the promoter region of *BMI1* and to the super-enhancer regions of *MET*, *EGFR*, and *TP63* (**Figure 5B and data not shown)**. These findings indicate that curcumin suppresses HNSCC tumorigenesis by inhibiting the recruitment FOSL1/JUN transcription complex to key oncogenic genes that drive malignant progression of HNSCC.

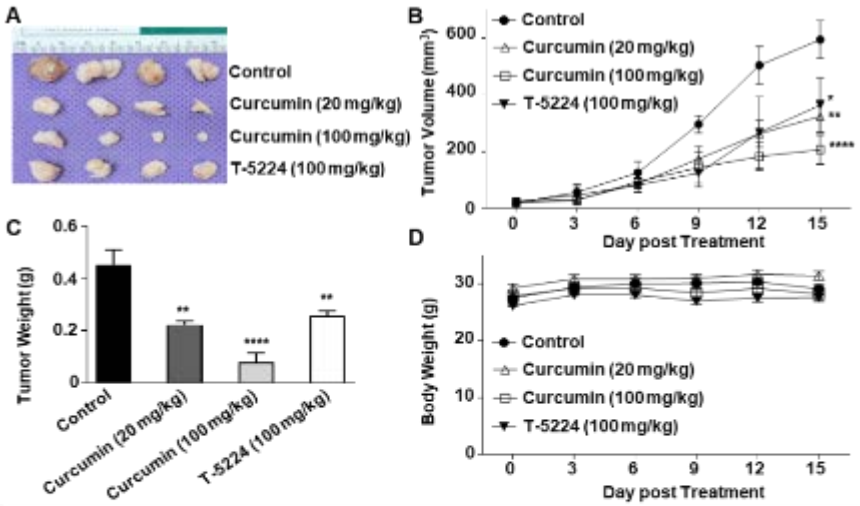

Figure 6. Curcumin suppresses HNSCC tumor growth *in vivo*. **(A)** Curcumin inhibited the growth HNSCC xenograft formed by UM-SCC1. Tumor images of mice treated with control vehicles, T-5224 (100 mg/kg), curcumin at 20 mg/kg and 100 mg/kg. **(B)** Quantification of tumor volume of UM-SCC1 xenograft. **(C)** Quantification of weight of UM-SCC1 xenograft. **(D)** Curcumin had little effect of the body weight change of the mice. Sidak's multiple comparison test $*P < 0.05$, $**P < 0.01$, $****P < 0.001$; n = 4.

Curcumin suppressed HNSCC tumor growth in xenograft mice model. A subcutaneous xenograft model was utilized to evaluate the anti-tumor potential of curcumin. UM-SCC1 cells were subcutaneously injected the flank of the NSG mice. After the tumors were formed, the tumor-bearing mice were treated with vehicle, or increasing doses of curcumin at 20mg/kg and 100mg/kg through intraperitoneal injection every other day for 15 days. T-5224, an AP-1 inhibitor, which has been suggested to suppress FOSL1-dependent transcriptional activity to suppress HNSCC tumorigenesis, was also included for treatment in parallel(Chen et al., 2017; Zaman et al., 2024; Zhang et al., 2021). As shown in **Figures 6A** and **6B,** tumor growth was significantly inhibited by the administration of curcumin at both doses. There are no significant changes in tumor volume or tumor weight between T-5224 (100mg/kg) and curcumin treatment at 20mg/kg, whereas both tumor volume and weight were significantly decreased in the 100mg/kg treatment group with improved potency over T-5224 (**Figure 6B & 6C**). Of note, administration of curcumin had little impact on the body weight of mice, suggesting that it is well tolerated by mice (**Figure 6D**). Altogether, these results demonstrate that natural compound, curcumin exhibit anti-tumor effects against HNSCC.

Discussion

In this study, we identified curcumin as a potent compound to suppress HNSCC tumorigenesis. Among the natural products tested, only curcumin demonstrated significant anti-tumor effects, exhibiting comparable or superior potency to cisplatin. Mechanistically, our findings reveal that curcumin exerts its anti-cancer activity through direct inhibition of the FOSL1/JUN transcription complex, a master regulator of oncogenic transcription and super-enhancer formation in HNSCC. These results uncover a previously unknown molecular mechanism of action of curcumin and provide compelling preclinical evidence supporting its therapeutic potential as a safe and affordable anti-cancer agent.

FOSL1 has been well-documented as a driver of malignant progression in multiple cancers. It regulates a transcriptional network that promotes stemness, drug resistance, and metastasis by establishing super-enhancers at oncogenic loci in HNSCC(Wang et al., 2024; Zhang et al., 2021). Our data demonstrate that curcumin directly binds to the FOSL1/JUN heterodimer with micromolar affinity and disrupts its DNA-binding capacity. This direct interference with the FOSL1/JUN transcriptional complex represents a novel mechanism distinct from the general anti-inflammatory or antioxidant effects previously attributed to curcumin. The inhibition of FOSL1 recruitment to super-enhancer–associated oncogenes provide a molecular explanation for curcumin's ability to suppress multiple malignant phenotypes of HNSCC cells, including proliferation, invasion, and self-renewal.

Importantly, our *in vivo* xenograft experiments demonstrated that curcumin suppressed HNSCC tumor growth in a dose-dependent manner and exhibited superior efficacy compared with the FOSL1 inhibitor T-5224, without detectable systemic toxicity. These findings not only validate the molecular observations in a physiological setting but also highlight the potential translational significance of curcumin as a well-tolerated and accessible therapeutic compound. Currently, there are no FDA-approved inhibitors targeting FOSL1 or the AP-1. T-5224 was originally designed to inhibit the FOS/JUN dimer and has advanced to Phase II clinical trials in Japan for the treatment of rheumatoid arthritis(Zaman et al., 2024). Although T-5224 has demonstrated the ability to suppress oncogenic FOSL1 signaling to inhibit tumorigenesis in multiple studies, its efficacy remains limited(Zaman et al., 2024; Zhang et al., 2021). The superior anti-tumor activity of curcumin observed in our study suggests that it may serve as a more effective scaffold for developing more potent FOSL1-targeting agents.

Despite these promising findings, several challenges remain. First, curcumin's poor bioavailability and rapid metabolism have long been recognized as barriers to its clinical application(Ahsan et al., 2020). Future studies should focus on developing improved formulations or delivery systems, such as nanoparticles, liposomes, or conjugated prodrugs, which have been reported to increase curcumin's stability and tissue accumulation(El-Saadony et al., 2022). Second, while our data establish FOSL1/JUN as a direct target of curcumin, it remains possible that curcumin may have additional roles in regulating transcription factors or signaling pathways that contribute to its overall anti-tumor activity. Comprehensive proteomic and structural analyses will be essential to delineate these potential off-target effects and to guide the rational design of more potent analogues.

In conclusion, this study identifies FOSL1/JUN as a novel molecular target of curcumin and provides a mechanistic framework explaining its anti-tumor efficacy in HNSCC. By directly inhibiting FOSL1/JUN recruitment to oncogenic loci, including super-enhancers, curcumin effectively suppresses FOSL1-dependent transcriptional programs and tumor progression. These findings not only advance our understanding of curcumin's mechanism of action but also underscore the therapeutic potential of natural, low-cost compounds as accessible anti-cancer agents, particularly in resource-limited regions where access to standard treatments remains restricted. Future clinical and pharmacological studies will be critical to translate these discoveries into viable therapeutic strategies for HNSCC and potentially other FOSL1-driven cancers.

Methods and Materials

Cell lines and cell culture. The human HNSCC UM-SCC1 cells were obtained from University of Michigan, and HN6 cells were from Wayne State University. These HNSCC cells were grown in Dulbecco's Modified Eagle Medium (DMEM) (Gibco, USA) supplemented with 10% fetal bovine serum (FBS) (Gibco, USA) and pen-strep antibiotics (Gibco, USA) at 37°C in a humidifier incubator supplied with 5% CO_2 environment. All the cell lines were tested to be free from mycoplasma contamination.

Streptavidin pulldown assay. Cellular extracts were obtained from UM-SCC1 cell. The cell extracts were incubated with biotinylated dsDNAs, mut DNA and scrambled DNA as in the presence of DMSO or Curcumin (50 μM) for 1h at 4 ºC. Streptavidin agarose beads (Dynabeads™ M-270 Streptavidin, Invitrogen) (20μL) was added to each reaction, followed by the incubation at 4 ºC for 2h. The beads were washed with PBS with 0.1% NP40 for three times, and proteins were eluted with 1X Laemli loading buffer at 100 ºC for 5 minutes. Western blot experiment was then conducted to observe the level of FOSL1 and JUN in the presence and absence of the compound.

Western blotting. After SDS-PAGE, the proteins were transferred into PVDF membranes via a semi-dry transfer protocol using the Trans-Blot turbo transfer system (Bio-Rad, USA). The membrane was blocked in 5% milk (Blotting Grade Blocker, Bio-Rad) then incubated overnight at 4 ºC with the indicated primary antibodies in 1% milk and followed by the secondary antibodies. All washing steps were performed in tris buffered saline containing 1% Tween 20 (TBST). The following primary antibodies were used for western blot: anti-FOSL1 (Cell Signaling Technology, #5281) and anti-JUN (Cell Signaling Technology, #9165).

Microscale thermophoresis. To calculate binding affinity of the compound we utilized microscale thermophoresis (Nano Temper Technologies, Cat# MO-L018). The purified recombinant His-tagged FOSL1:JUN fusion protein was labeled with the RED-tris-NTA 2nd generation dye by mixing equal volumes of protein and dye solutions, followed by incubation at 4 ºC for 30 minutes. Simultaneously, twelve different concentrations range were prepared in the MST buffer by serial half dilution. To each concentration an equal volume of the labeled protein was added. The binding affinity (K_d) value was determined by measuring concentration dependent change in fluorescence using standard MST capillaries at room temperature. The K_d value of each compound was calculated with the GraphPad prism software.

Quantitative reverse transcription polymerase chain reaction (RT-qPCR). To measure the mRNA expression levels, cells were plated in 6-well plates and upon attachment cells treated with compound at 50$^{\mu M}$. After 24h post treatment the total RNA was isolated using the Nucleospin RNA Plus isolation kit (Macherey-Nagel, Germany). The extracted mRNA was reverse transcribed to cDNA by the enzyme reverse transcriptase using M−MuLV reverse transcriptase kit (New England Biolabs, USA). RT-qPCR were then performed in Realtime-PCR instrument using SyBRGreen Supermix (Bio-Rad).

Tumor sphere formation assay. UM-SCC1 or HN6 cells were then seeded into ultra-low attachment 24-well plates at 1000 cells/well in serum-free MEBM (Lonza, USA) supplemented with 2% B27 (Gibco, USA), 20 ng/mL EGF (R&D Systems, USA), 10 ng/mL FGF (R&D Systems, USA), 4 mg/mL Gentamicin (Invitrogen, USA), 5 µg/mL Insulin and 100 µM β-mercaptoethanol (Sigma-Aldrich). The medium was replenished every three days up to 2 weeks at which point the spheres were assessed via microscopy. The spheres having diameter of ³40 µm were counted to perform the statistical analysis as described(Zhang et al., 2021).

Animal study. UM-SCC1 cells (1x10^6 cells) were subcutaneously injected to the NSG mice onto the left flank. The tumour bearing mice were randomly segregated into four groups (n=4) and two doses of Curcumin, (20 mg/kg or 100 mg/kg), T-5224 (100 mg/kg) and vehicle composed of PBS and Kolliphor EL (Sigma-Aldrich) were administered intraperitoneally every other day for 14 days. The tumour measurements were recorded for every three days using digital calliper. After 15-days of treatment, mice were euthanized and tumour were collected. The experimental procedures were conducted in accordance with the Guidelines for Care and Use of Laboratory Animals of Virginia Commonwealth University and approved by the Animal Ethics Committee (IACUC AD10002119).

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Microstructure-Resolved Design of Porous Dielectric Membranes for Ultrathin Capacitive In-Stent Intracranial Pressure Sensors

Abstract

Recent advances in non-surgical, in-stent pressure sensors have allowed for minimally invasive, continuous monitoring of intracranial pressure (ICP), overcoming traditional limitations in ICP monitoring. However, the literature on these advancements fails to investigate factors that affect the microstructural mechanics of the dielectric membrane, despite their key influence on the electromechanical performance and mechanical stability. This study addresses these shortcomings through microstructural studies of sacrificial three-dimensional (3D) templates and their resulting electromechanical performance. Hence, a monodisperse sacrificial template was chosen to systematically examine the correlation between pore-scale architecture—porosity and pore size—and the electromechanical response across physiologically relevant pressure ranges for ICP monitoring. Intermediate porosity and pore-size microstructure in the dielectric layer made with monodispersed particles demonstrated an optimal sensitivity that did not compromise the linearity or mechanical longevity of the capacitive pressure sensor (CPS). When the optimized porous dielectric membrane is under ultrathin dimensions in a non-surgical in-stent intracranial pressure sensor, it accurately detects low-amplitude pressure oscillations within the clinically relevant ICP range without drift. By exhibiting and elucidating the link between pore size/porosity and sensing performance

of CPS under ultrathin constraints, this study provides a materials-level foundation for improving the sensitivity and clinical reliability of future pressure-monitoring devices.

Introduction

Continuous intracranial pressure (ICP) monitoring is vital for diagnosing and managing various severe neurological conditions. Current gold-standard methods require highly invasive skull punctures, which limit long-term and repeated measurements due to the risks of infection and hemorrhage (Czosnyka et al., 2004; Munakomi et al., 2024): infection rates can reach 5.9% and hemorrhage rates can reach 31.9% (Tavakoli et al., 2017; Chen et al., 2023). Recent advances in ICP monitoring have demonstrated the feasibility of minimally invasive, ultrathin, in-stent capacitive sensors for continuous ICP monitoring without cranial penetration (J. Lee et al., 2025). However, these innovations are limited by the dielectric design of the ultrathin, in-sentent dielectric membrane—an unexamined microstructure. Like previous demonstrations, the porous elastomeric element of the dielectric membrane was included to empirically increase sensitivity (J. Lee et al., 2025; Hwang et al., 2021). However, the performance of porous membranes as dielectrics is governed by a multitude of microstructural elements, such as the Young's modulus, longevity, and electromechanical response. Pore size and porosity, in particular, are often conflated, despite their independent effects on microstructural elements regarding the CPS. This raises a materials-level question about how microstructural properties in the dielectric membrane influence various pressure sensor performance, especially in in-stent ultrathin CPS.

In this study, the materials-level question is investigated through microstructure-focused experimentation on porous polydimethylsiloxane (PDMS) dielectric membranes for ultrathin CPS. By investigating the optimal tuning of pore size and porosity created by three-dimensional (3D) sacrificial template materials through a variety of pressure-capacitance testing, this study establishes that using monodisperse sacrificial templates directly links dielectric microstructure to pressure-sensing performance in capacitive pressure-sensing units. With this approach, an optimized dielectric membrane is identified and created to simultaneously maximize sensitivity while preserving mechanical longevity in ultrathin in-stent CPS under physiologically relevant conditions. These results demonstrate the beneficial effects of microstructural optimization on porous dielectric membranes in ultrathin in-stent CPS for ICP monitoring.

Materials and Methods

Template Material Study: This study aimed to determine the pore microstructure of porous PDMS dielectrics resulting from different 3D sacrificial templates. If a templating strategy that produced uniform pore distributions with well-defined pore sizes were identified, then the correlation between pore size, porosity, and capacitive pressure-sensing performance could be systematically studied (Figure 1A). PDMS mixtures were prepared at a 1:10 curing-agent-to-base weight ratio, with each sample containing 24 g of PDMS. The mixtures were either left unmodified as a non-templated control, mixed with granulated sugar crystals at a 2:1 PDMS-to-template weight ratio, or with monodispersed polystyrene (PS) beads at an 8:1 ratio. Granulated sugar was chosen

as a polydispersed 3D template to assess the limitations of non-uniform sacrificial templates. PS beads were chosen as a monodisperse particle that could remain stable during PDMS curing and enable control of pore size and porosity. Before heat curing, all mixtures were degassed for 30 mins. Sugar-templated PDMS was cured in an oven at 60°C for 24 h. The sugar was then removed by submerging the PDMS in deionized water at 80°C for 24 h. PS-bead-templated and plain PDMS were cured on a hotplate at 100°C for 1 h, with aluminum surrounding each petri dish. The PS beads were removed by immersion in tetrahydrofuran at 50°C for 24 h (nitrile gloves, protective eye equipment, and safety precautions were taken when handling tetrahydrofuran). Then, all cured PDMS films were dried in a fume hood for at least 24 h to evaporate solvents, stabilizing the microstructure. Lastly, PDMS films were cut into samples using a femtosecond laser cutting system to prevent structural damage that could hinder the morphology study. To gain a quantitative comparison of pore homogeneity and structural uniformity for later optimization and sensing-performance evaluation, samples were characterized using optical microscopy (OM) and micro-computed tomography (micro-CT).

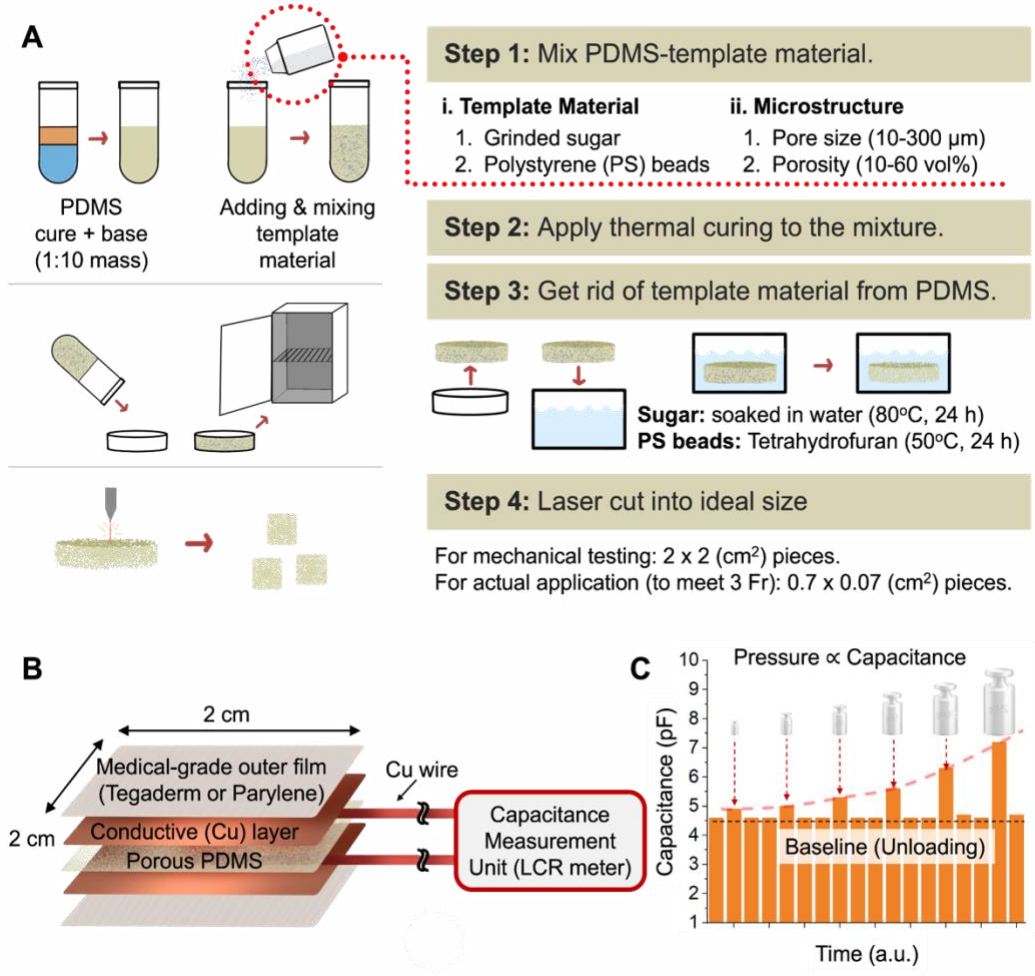

Figure 1: Overview of porous PDMS fabrication and pressure-capacitance CPS testing. (A) Schematic illustration of fabrication process: PDMS preparation, template mixing, thermal curing, template removal, and laser cutting into the ideal size. (B). Layered

schematic of the CPS unit. (C) Relationship between the applied pressure and the corresponding capacitance response of the fabricated CPS unit.

Pore Size and Porosity Control Using Monodisperse PS Templates: Capacitive pressure sensor (CPS) units, parallel-plate capacitors, were fabricated through a simple layered sandwich structure of two thin-film copper electrodes and a porous PDMS dielectric membrane (Figure 1B). Each CPS unit consists of two top and bottom square copper (Cu) electrodes as conductive plates. Narrow extension tabs were patterned on opposing corners of each Ci electrode for electrical connection wires. Soldering paste was applied to the Cu electrodes to solder a conductive Cu wire in a U-shape along the extension tab. With two Cu electrodes, they were combined to sandwich the PDMS dielectric layer. Lastly, the sandwiched CPS unit was encapsulated in a layer of medical-grade Tegaderm film for electrical insulation, mechanical stabilization of layers, and protection against microstructural damage from fluids. To compare CPS units templated with different materials, 2 × 2 cm CPS units were subjected to static capacitance-pressure testing across a clinically relevant ICP range of ~2 to 40 mm Hg (Munakomi, Das, 2024). Incremental pressures of 1.84, 3.68, 9.20, 18.4, and 36.8 mmHg were applied to CPS units. The data were recorded using an LCR meter and a custom LabVIEW program for real-time data collection (Figure 1C).

Miniaturized In-Stent CPS Integration: Optimized CPS units were miniaturized into ultrathin film sensors with a thickness of hundreds of micrometers, 0.7 mm wide, and 7 mm long. Each miniaturized CPS was electrically connected to the distal end of a 170 cm-long guidewire, enabling capacitance measurements to be performed from the proximal end (Figure 2A).

For stable positioning under continuous fluid flow, the guidewire-mounted CPS was mechanically integrated with a self-expanding commercial stent (Figure 2B). The guidewire and stent were combined through a heat-shrink tube to preserve both flexibility and electrical properties. The guidewire, stent, and sensor device were loaded into a commercial guide catheter.

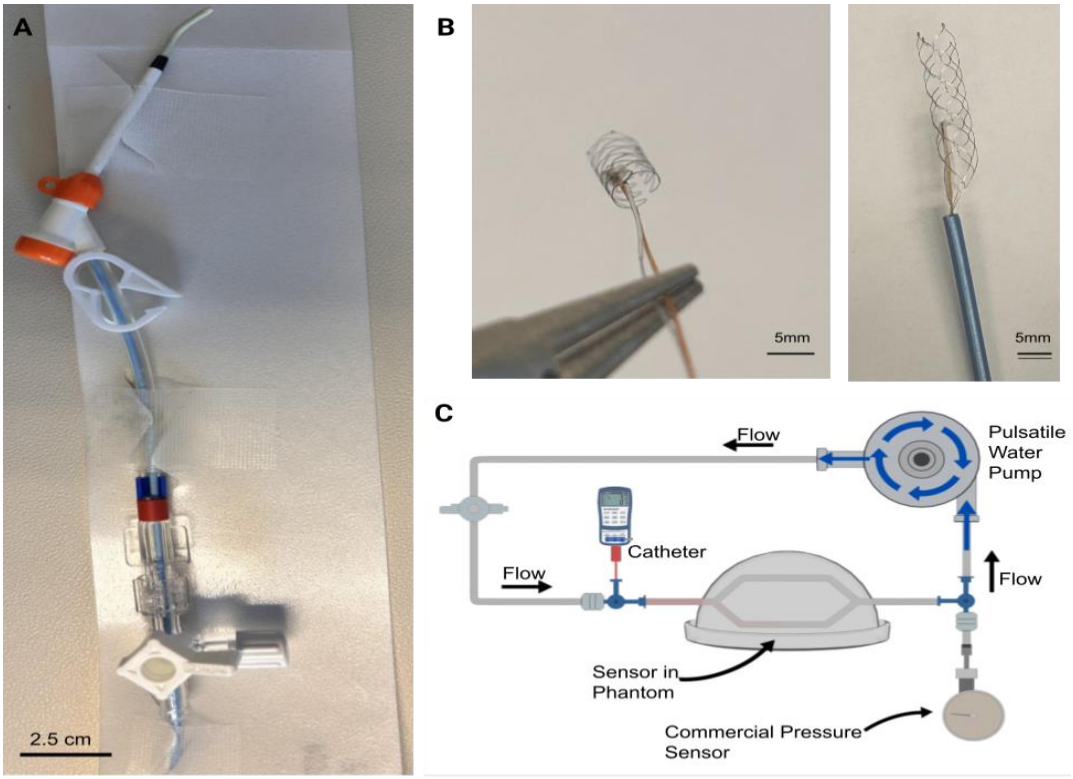

Figure 2: (A) Guide catheter device used for sensor deployment. (B) Fully deployed in-stent biosensor with optimized dielectric membrane. (C) Experimental setup for in-vitro ICP monitoring in an in-house cranial cavity phantom

In-House Cranial Cavity Phantom Model: An in-house cranial cavity phantom that mimics cranial conditions was used to evaluate real-time capacitance monitoring performance of the optimized CPS. Developed by KB Lee et al. in a previous study, it consisted of silicone tubing and was connected to a water pulsatile pump at 60 rpm, with 0.08 M saline solution circulating through the system to emulate both fluid (venous viscosity of 3–4 cP at 21°C) and electrical dural venous conditions (DVS), a surrogate for ICP monitoring. The guidewire-integrated CPS device was deployed and positioned in the tubing, as shown in Figure 2C, and capacitance signals were recorded using an LCR meter interfaced with a LabVIEW program. The system was subjected to increasing pulsatile pressure that reached a peak of 15mm Hg and reset to 5mm Hg after 150 seconds of gradual increase over ~4,000 seconds.

Results

Template Material Study: To compare sacrificial 3D template materials reported in literature (Zhao et al., 2024; González-Rivera et al., 2018; Dan et al., 2019), comparative pressure-capacitance testing and quantitative microstructural evaluation were performed. OM imaging showed clear differences in pore morphology across the

three dielectric types, as seen in Figure 3A. Solid PDMS (the non-templated PDMS mixture) exhibited a poreless morphology; sugar-templated PDMS exhibited irregular, incomplete pores of varying sizes; PS bead-templated PDMS displayed universally uniform, well-defined pores.

Electromechanical responses using 2 × 2 cm CPS units in incremental capacitance-pressure testing were recorded (Figure 3B). PS bead-templated PDMS exhibited the highest slope of 0.06854 pF/mmHg^{-1}, with a linear fit (R^2 = 0.993). Solid PDMS exhibited a moderate sensitivity of 0.03959 pF/mmHg^{-1}, with a linear fit R^2 of 0.996. Sugar-templated PDMS exhibited the lowest sensitivity of 0.03917 pF/mmHg^{-1}, with an R^2 of 0.989. These results indicate that the template material is able to significantly influence both the overall sensitivity of the CPS and the pore morphology. They also indicate that PS beads yield a monodisperse pore morphology. This indication can then be used for systematic optimization of pore size and porosity.

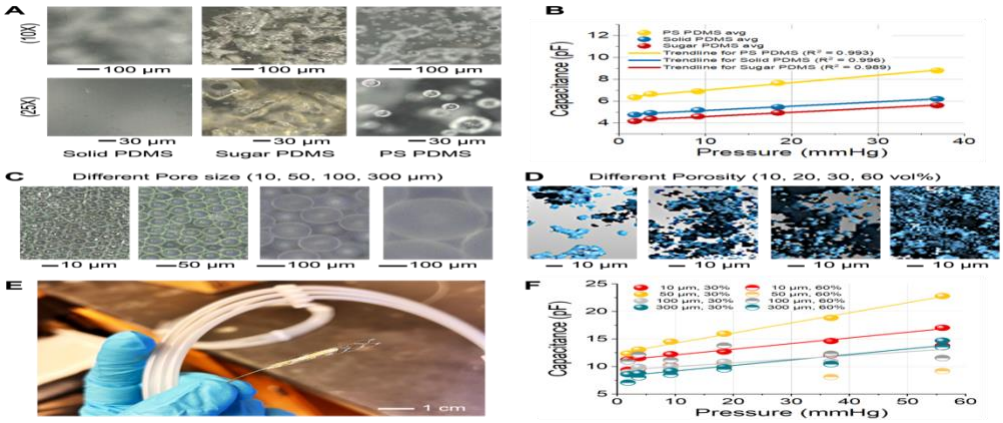

Figure 3: (A) OM imaging results of porous PDMS pore structure (top row), PDMS before template material was removed (bottom row). (B) averaged results of template material static capacitance-pressure testing in pF/mmHg. (C) OM image comparison of PS beads varying in diameters: 10, 50, 100, and 300 µm (left to right). (D) Micro-CT comparison of PS-bead-templated-PDMS porosities varying in vol%: 10, 20, 30, and 60 vol% (left to right). (E) Successful integration of the ICP monitoring device and porous polymer dielectric. (F) Measurements of capacitance-pressure performance of dielectric layers of varying pore diameters: 10, 50, 100, and 300 µm, matched with varying volume percentages, 30% and 60%.

Pore Size and Porosity Optimization Using PS Templates: After the preliminary template material testing, the effects of porosity and pore size on pressure sensor sensitivity of the CPS units were systematically investigated using the PS-bead templated PDMS. OM imaging verified that PS bead diameter translated to pore size, exhibiting corresponding uniform pore size with PS bead diameters of 10, 50, 100, and 300 µm (Figure 3C). Micro-CT further showed clear three-dimensional pore distributions as a function of porosity (10, 20, 30, and 60 vol%) (Figure 3D).

In capacitance–pressure measurements, PS beads were chosen as the templating material for their ability to control porosity and pore size. PS beads of different diameters (10, 50, 100, and 300 µm) and PS bead-to-whole volume percentages (30 and 60 vol%) were matched to produce porous PDMS with varying pore sizes and

porosities (Figure 3F). However, PDMS films with pore diameters of 100-300 μm and porosities of 10-20 vol% were excluded for reasons explained later. Dielectric layers of 50 μm beads at 30 vol% porosity provided the highest sensitivity of 0.18393 pF/mmHg, showing excellent linearity and repeatability across pressure ranges. The second and third-most sensitive configurations were 10 μm at 30 vol% and 10 μm at 60 vol%, with sensitivities of 0.10299 pF/mmHg and 0.07924 pF/mmHg, respectively.
Consistent with all pore sizes, 30 vol% porosity exhibited the highest sensitivities. It should be noted that PDMS films with 100-300 μm pores were difficult to process using laser cutting due to the large and irregular voids. Furthermore, films with 60 vol% porosity had walls that were too thin to withstand the laser cutting process (Figure 3D). Configurations with large pore sizes (≥100 μm) or high porosity (60 vol%) exhibited reduced repeatability during testing and were excluded from further device integration. Using the optimized porous Ps bead-PDMS formulation, the final CPS unit was fabricated and cut into 0.7 × 0.07 cm^2 segments for integration with a stent-based delivery platform (Figure 3E).

In Vitro Testing: The completed CPS–stent device with optimized microstructure was evaluated in a custom-built cranial-cavity phantom to mimic DVS pressure. Capacitance signals were recorded externally for over ~1600 repeated cycles for over 4,000 seconds, increasing-and-resetting at physiologically relevant pressures in the 5-15 mmHg range (Figure 4A) [Munakomi, Das, 2024]. The capacitance signal exhibited pulsatile variations that closely reflected the ICP waveforms observed in the settings. Furthermore, it exhibited synchronized cyclic modulation corresponding to pressure cycles, indicating high temporal sensitivity to dynamic pressure changes (Figure 4A-B). Longevity was assessed under constant-pressure conditions by continuously recording capacitance for approximately 4,000 s. (Figure 4C). The signal remained stable throughout the monitoring period, with no observable baseline drift or amplitude degradation, confirming the suitability of the optimized CPS for prolonged pressure monitoring.

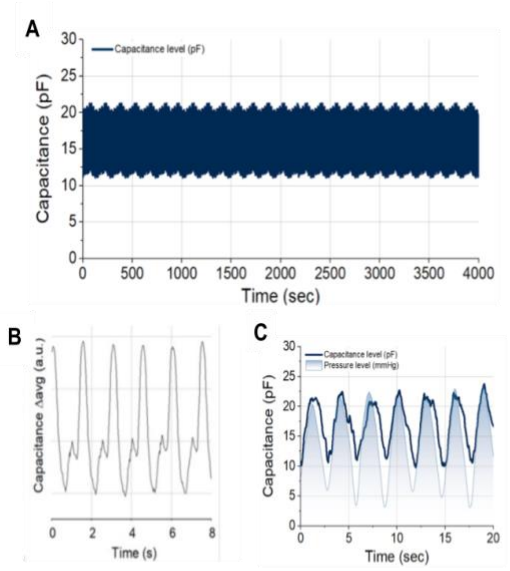

Figure 4: **A)** Long-term capacitance recording over a ~4,000-second period under constant pressure conditions, illustrating stable, continuous operation and minimal signal drift. **B)** Closer 8-second examination of the pulsatile readings from ICP sensor that closely mirrors the real pulsatile nature of ICP waveforms. **C)** Real-time monitoring of pulsatile ICP dynamics over a 20-second window of capacitance variation recorded from the intracranial DVS phantom connected to a pulsatile water pump.

Discussion and Conclusions

Template Material Study: In a parallel plate capacitor, the formula ($C = \frac{\epsilon A}{d}$) shows that changes in distance create the greatest change in capacitance. Additionally, Young's modulus can be approximated using a porous foam model, $\frac{E}{E_0} = (1-\phi)^n$, where ϕ is the porosity and n≈2 because PDMS is an elastometric foam. Therefore, the enhanced performance of PS bead-templated PDMS is likely attributable to the uniform pore distribution and size previously observed in OM images (Figure 3C) and micro-CT (Figure 3D). This uniform porosity reduces the effective Young's modulus and increases the mechanical compliance under load. The theoretically estimated Young's modulus demonstrates an inverse trend with porosity and Young's modulus: 10% porosity = 1.46 MPa, 20% = 1.15 MPa, 30% = 0.88 MPa, and 60% = 0.29 MPa. OM imaging reveals that the sugar-templated PDMS exhibited an irregular pore morphology. This could have reduced the Young's modulus, but also reduced the distance between the two plates, compromising any further measurements. If this irregular morphology led to structural degradation when subjected to load, it would explain why sugar-templated PDMS had the lowest sensitivity, lower than even the solid PDMS. Solid PDMS demonstrated a higher Young's modulus because it did not have any pores. Thus, there

was no degradation and the change in distance between the electrode plates was minimal, resulting in medium pressure-capacitance sensitivity.

It is worth noting that the heterogeneous pore distribution observed in sugar-templated PDMS is primarily attributable to the thermal curing conditions. To avoid the melting of the sugar crystals, long-duration curing was performed at 60°C. Although not shown, preliminary feasibility studies conducted at 100°C confirmed partial melting of sugar crystals. These melted sugar phases failed to remain uniformly dispersed within the PDMS matrix and instead migrated upward, forming a distinct layered structure. However, curing at the lower temperature of 60°C introduced additional challenges. Specifically, the reduced temperature resulted in (i) significantly slower PDMS crosslinking kinetics and (ii) phase separation driven by density mismatch between sugar crystals and the PDMS prepolymer (Massachusetts Institute of Technology, n.d.; PubChem, n.d.), causing the sugar particles to sediment toward the bottom of the mold during curing. Consequently, residual sugar powders were observed at the bottom of the fully cured PDMS, resulting in non-uniform porosity and degraded dielectric performance.
These outcomes indicate that, despite its conceptual simplicity, sugar templating is highly sensitive to curing conditions and prone to pore inhomogeneity, which directly compromises pressure sensitivity. In contrast, PS bead templating enables quicker thermal processing and yields reproducible, uniform pore architectures, resulting in superior electromechanical performance.

Pore Optimization Study: The range of the pressure sensor's intended use should dictate the Young's modulus. Fifty μm beads at 30 vol% porosity were found to perform the best because of the balance between the air fraction and an optimized Young's modulus for sensitivity. Although the 10%-20% conditions were not shown in Figure 3F, pores formed primarily on the surface of the polymer block during fabrication. Naturally, the low porosity translates to low air fraction, which translates to a high Young's modulus, creating a less sensitive dielectric layer that acts similarly to solid PDMS. The clustering at the surface can be credited to the tendency toward delayed inner curing, which causes early surface immobilization of PS bead particles.
Furthermore, for pores with diameters of 100 and 300 μm, the pore size was too large and the pore-to-pore distance too small, resulting in walls too thin to withstand laser cutting and pressure induced degradation.
Previous studies have established the relation between porosity in PDMS, the Young's modulus, and sensitivity. However, they do not address both microstructural components simultaneously and control pore size to the degree in this paper (Zhu et al., 2023; Masihi et al., 2021; Bilent et al., 2019; Bu et al., 2024; Bijender, Kuma, 2023). Here, we independently control both pore size and porosity to precisely link them to capacitive pressure sensing under ultrathin constraints.

Study	What Was Systematically Controlled	Dielectric/Microstructural Method	Converted Sensitivity ($\Delta C/C_0$ per mmHg)

J. Lee et al. (2025)	Surface geometry (micro-pyramids)	Mold-replicated microstructured PDMS membrane	0.052 $\Delta(C/C_0)$/mmHg
Zhu et al. (2023)	Foam density (indirect)	Chemically foamed porous elastomer	0.028 $\Delta(C/C_0)$/mmHg
Masihi et al. (2021)	Dielectric thickness	Solid PDMS capacitive sensor	0.00067 $\Delta(C/C_0)$/mmHg
Bilent et al. (2019)	Overall porosity (qualitative)	Salt/sugar sacrificial templating	0.016 $\Delta(C/C_0)$/mmHg
Bu et al. (2024)	Composite filler loading	Elastomer–air composite dielectric	0.041 $\Delta(C/C_0)$/mmHg
Bijender, Kumar (2023)	Template concentration	Random porous PDMS via leaching=	0.024 $\Delta(C/C_0)$/mmHg
This Study	**Pore size and porosity**	PS bead templating	**≈0.148 $\Delta(C/C_0)$/mmHg**

Table 1: Comparison of different literature to highlight how this study differs

In Vitro Testing: The optimized CPS was tested under the physiologically relevant conditions in a DVS phantom to confirm its feasibility for continuous ICP monitoring. The 0-8 second monitoring shows pulsatile differences in capacitance responses and demonstrates the basic level of sensitivity needed. This is because clinical diagnosis is highly dependent on the visualization of ICP waveforms [Munakomi, Das, 2024]. The CPS sensor's ability to reproduce periodic capacitance responses suggests a similar capability to the optimized microstructure, not under ultrathin conditions: rapid elastic response and minimal viscoelastic damping within physiologically relevant conditions.
It was theorized that the intermediate pore size and porosity promoted uniform deformation across the dielectric layer. Therefore, pressure-induced changes in the dielectric layer were reversible, enabling stable capacitance monitoring during sustained low-pressure cycles. Long-term stability testing further confirms these theories of the optimized CPS's longevity.
The 4,000 s of constant physiologically relevant pressures showed negligible baseline drift and no degradation in signal amplitude. These robust measurements under sustained low-pressure cycles suggest that the optimized pore structure can mitigate structural relaxation over time, which can compromise a CPS sensor, thereby validating the feasibility of the sensor in continuous ICP monitoring using the optimized microstructure.

Conclusion: The materials-level question of how microstructural properties in the dielectric membrane influence various pressure sensor performances is investigated through studies of the resulting microstructure from 3D sacrificial template materials,

optimization of pore size and porosity, and a variety of pressure-capacitance tests. Through these studies, PS beads, a monodispersed particle, are found to show controllable, uniform pore size and porosity. This finding is used as the foundation for independently controlling pore size and porosity in the dielectric layer of CPS, creating controlled porous microstructures to a degree not reported in other studies. This templating strategy is used to create an optimized porous dielectric membrane within an in-stent CPS sensor for ICP monitoring under ultrathin constraints, maximizing sensitivity without compromising mechanical longevity under physiologically relevant conditions. These results show that microstructural optimization of porosity and pore size is feasible and beneficial for porous dielectric membranes under ultrathin in-stent CPS for ICP monitoring.

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Combating Alzheimer's Disease via Immunotherapy: In-Silico Design of Novel CAR scFv Proteins for Targeted Inhibition of RAGE-Mediated Microglial Activation

ABSTRACT

Alzheimer’s disease (AD) is the most prevalent neurodegenerative disorder, affecting over 50% of 80+ aged individuals worldwide. RAGE is a pro-inflammatory receptor expressed on microglial cells in the brain. Its interaction with molecules like advanced glycation end products (AGEs) and amyloid-beta plaques trigger pro-inflammatory phenotype acquisition in immune cells called microglia, leading to neural tissue damage/degeneration. CAR Treg cell therapy is an emerging immunotherapy treatment where regulatory immune cells called Treg cells are designed to recognize inflammation-indicative biomarkers (e.g., RAGE) and release anti-inflammatory cytokines to halt pro-inflammatory signaling. This research aimed to design novel RAGE-targeting scFvs, which are portions of CAR proteins that interact with target biomarkers (e.g., RAGE) and induce cytokine release, to implement into CAR design. Nine scFvs (S1-S9) were designed with the DiffAB software, and molecular docking was performed to determine binding strength towards RAGE. A higher binding strength is optimal, indicating that the scFvs effectively bind to RAGE. Additionally, electrostatic

interactions between each scFv and RAGE were analyzed using the PLIP server. The top two best-performing scFvs with the highest binding strength, S3 and S4, were further subjected to (1) molecular dynamics (MD) to determine time-dependent stability and (2) molecular docking with BBB adhesion proteins to determine brain permeability. MD revealed that S3 exhibited significantly lower RMSD and Rg fluctuations than S4, indicating it is more structurally stable over a comprehensive timeframe. Furthermore, S3 demonstrated more optimal binding towards BBB adhesion proteins than S4, indicating it can effectively enter the brain and target microglial cells. Overall, S3 outperformed S4 due to its higher stability when bound to RAGE and increased ability to enter the brain, necessary to then target the resident microglial cells. Nonetheless, limitations like constant temperatures/ion concentrations, which misrepresent true physiological conditions, and potential algorithmic errors necessitate validation using hands-on testing. In conclusion, this study presents S3 as a promising therapeutic for Alzheimer's and potential to succeed in future laboratory and clinical testing.

INTRODUCTION

Alzheimer's Disease (AD) is one of the most prevalent neurodegenerative disorders, affecting 10% of 60+ aged individuals and 50% of 80+ aged individuals globally (Zhang et al., 2011). Nearly 45 million people had Alzheimer's in 2019, and this number is expected to triple by 2050. In addition, over 60% of all dementia is caused by Alzheimer's (Zhang et al., 2019). A small subset (<10%) has an autosomal dominant mutation in the genes encoding amyloid precursor protein (APP), presenilin 1 (PSEN-1), and presenilin 2 (PSEN-2). Patients with these mutations often develop hereditary, early-onset Alzheimer's that can be passed onto offspring. The remaining majority, however, do not have mutations in these genes. AD is characterized by an insidiously progressing dementia that affects critical regions like the hippocampus and cerebral cortex, involved in memory and high-order processing (Schindler & Fagan, 2015).

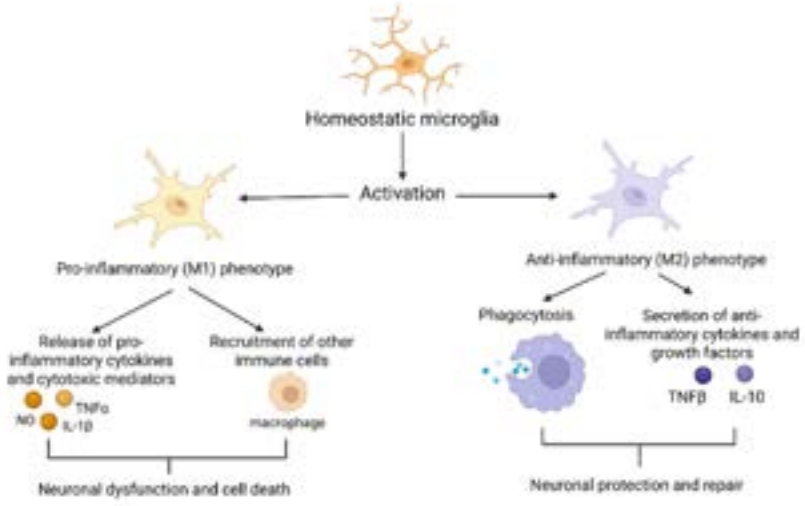


Figure 1. AD Pathology. (a) Microglial cells are originally in their inactive (homeostatic) state, but activation can cause them to express either pro-inflammatory (M1) or anti-inflammatory (M2) phenotypes.

The most commonly agreed molecular mechanisms of AD pathogenesis are the aggregation of extracellular amyloid beta (Aβ) and intracellular neurofibrillary tangles containing hyperphosphorylated tau in neurons. Both features induce proteotoxic conditions, causing interference with neural communication (i.e. synaptic dysfunction) and neuronal cell death (Zhang et al., 2011). However, recent research has revealed that microglia-mediated pro-inflammatory stimulation and oxidative stress is another critical hallmark. Neuroinflammation is mainly mediated by microglia, immune cells in the central nervous system (CNS). Two activated microglial phenotypes exist: the pro-inflammatory M1 and the anti-inflammatory M2 phenotype. M1 microglia are pro-inflammatory, releasing toxins to combat pathogens and destroy damaged tissue; M2 are anti-inflammatory, releasing anti-inflammatory mediators that promote tissue regeneration. Chronic activation of microglia towards M1 phenotypes causes them to become dysfunctional and destroy healthy brain tissue and cause neurodegeneration. Activation of M2, on the contrary, can minimize inflammation and reduce tissue damage, indicating therapeutic potential (Muzio et al., 2021).

RAGE is an inflammation-causing receptor that is largely expressed in microglial cells. The interaction of pro-inflammatory signals (e.g., AGEs, S100, calgranulins) with RAGE plays a crucial role in driving microglia towards M1 pro-inflammatory phenotypes. RAGE activation activates NADPH oxidase, an enzyme that activates transcription factor nuclear factor kappa B (NF-κB). NF- κB promotes expression of pro-inflammatory genes that mediate the release of inflammation-causing cytokines like interleukin-1beta (IL-1β), tumor necrosis factor-alpha (TNF-α), vascular cell adhesion molecule-1 (VCAM-1), intercellular adhesion molecule-1 (ICAM-1), plasminogen activator inhibitor-1 (PAI-1), and monocyte chemoattractant protein-1 (MCP-1), which all contribute to neurodegeneration (Cai et al., 2016; Prasad & Mishra, 2018). Interestingly, Aβ frequently interacts with RAGE during AD, indicating that RAGE activity is frequently involved in Aβ-mediated AD progression.

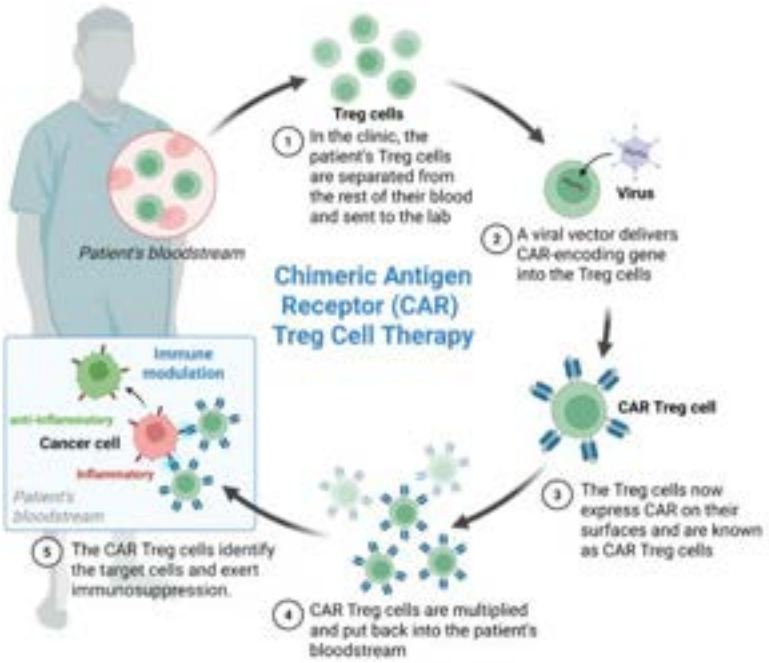


Figure 3. CAR Treg cell therapy workflow. Treg cells are extracted from patients and transfected with a CAR gene using a viral vector for delivery. The recombinant Tregs, which express the target CAR protein, are reintroduced into the bloodstream where they can bind to the target cells and minimize its immune activity.

CAR T-regulatory (Treg) cell therapy is an emerging cutting-edge immunotherapy where immune cells called T-regulatory (Treg) cells are genetically modified to express receptor proteins that bind to disease-causing proteins and biomarkers. Upon binding to these target proteins (antigens), the Treg cell will release specific signaling molecules (cytokines) into the target cells that downregulate overactive immune responses, such as those observed in M1 microglial phenotypes (MacDonald et al., 2016). In this procedure, the patient's Treg cells are first extracted from serum, and a viral vector delivers a CAR-encoding gene into the Treg cells; the recombinant Treg cells will now express the modified CAR protein (Cochrane et al., 2025). The extracellular domain of the CAR protein (which is responsible for binding to the antigen) contains an scFv fragment that specifically serves to recognize the antigen (Mohseni et al., 2020). Up to this point, no CAR proteins have been designed which specifically target the RAGE receptor protein. In fact, research on anti-RAGE antibodies for therapeutic purposes itself is highly limited and requires further research (Dong et al., 2022). RAGE-targeting CAR Treg cells can release anti-inflammatory cytokines into microglial cells that will terminate the M1 phenotype and drive microglia towards anti-inflammatory M2 phenotypes; this will minimize tissue damage and neurodegeneration. Therefore, designing novel CAR proteins to prevent RAGE-mediated neuroinflammation offers novel therapeutic insights into preventing AD progression.

Current drug discovery processes are high-risk, costly, and largely susceptible to failure. Nearly 10-15 years of time and over $2 billion USD are oftentimes invested into drug design. Additionally, 90% of drugs entering clinical trials fail to gain FDA approval, 75% of which are from errors/inefficacies in laboratory and clinical procedures (Sun et al., 2022). Computer-aided drug discovery (CADD) is a growing field in medical

technology which uses computational modeling to identify and design optimal drugs. CADD technologies can rapidly screen hundreds of therapeutics like CAR proteins and narrow down top-performing ones that can then be considered for experimental/clinical validation. Hence, clinicians and laboratory scientists would not have to invest time and expenses into drugs that are ineffective in the first place. By reducing the amount of manual testing required, CADD offers a promising complement to hands-on testing that speeds up and enhances the drug discovery process.

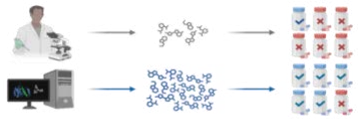


Figure 4. Computer-aided techniques design can streamline drug design and greatly improve accuracy in combination with laboratory testing, as opposed to mere hands-on testing alone.

The purpose of this study is to test the binding strength of various scFvs (differing by amino acid sequence) to the extracellular region (ectodomain) of the RAGE receptor protein; the ectodomain is where RAGE-targeting ligands and drugs). Optimal binding indicates that the scFv can be effectively utilized for RAGE-directed CAR Treg cell therapy and anti-inflammatory phenotype acquisition of microglial cells. Furthermore, molecular dynamics (MD) simulations were performed to determine time-dependent stability of the top two scFv proteins when bound to RAGE. The top two scFvs were further assessed for blood brain barrier (BBB) transmigration potential to determine how effectively they can enter the brain. The MD simulations and brain entry potential were assessed to determine the best-performing scFv overall. It was hypothesized that the designed scFvs will strongly/stably bind to the RAGE ectodomain and enter the brain, so they can then be utilized to create novel immunotherapeutic CAR proteins. As no medically used anti-RAGE scFvs exist based on current literature, no positive control was used in this research.

METHODS/MATERIALS

3D Structure Determination of Proteins:

Macromolecules like sugars, proteins, and nucleic acids, adopt a 3D structure that enables them to carry out their respective biological functions; therefore, the 3D structure of each scFv and the RAGE ectodomain was determined to effectively model their interactions in a biological setting. The DiffAb software from the NeuroSnap server was utilized to design nine novel anti-RAGE scFvs and obtain the scFv amino acid (FASTA) sequences. The FASTA sequence of each scFv was inputted into the AlphaFold 3 software to determine each of the nine scFvs' 3D structure. The 3D receptor structure of the RAGE ectodomain (i.e. the part which binds to the scFvs) was obtained from the Protein Data Bank (PDB) website (PDB ID: 4P2Y). The RAGE and scFv 3D structures were saved as PDB files in a working directory for further use.

RAGE Ectodomain Visualizations & Druggable Site Prediction:

The RAGE ectodomain 3D structure was input into the Chimera X software to visualize the following: (1) rainbow coloring, which visually relates the linear amino acid sequence of the protein to the final 3D structure, providing information on its mechanisms of protein folding; (2) space-filling model, which shows the individual atoms of the protein; and (3) semi-transparent model, which includes both the 3D ribbon backbone representations and an outer semi-transparent surface visualization (Figure 6). Furthermore, the electrostatic surface potential (surface charges) was determined to analyze charge distributions across the protein, particularly at its druggable site. Analyzing the surface charges at the druggable site can be used to determine the required charge for the scFvs (e.g., a positively charged druggable site requires negatively charged scFvs and vice versa). The GrASP server, that uses graph neural networks (GNNs), was used to find the specific druggable binding site within the RAGE ectodomain; this druggable site is where molecules like scFvs must bind to demonstrate anti-RAGE activity.

Molecular Docking and Molecular Dynamics Simulations:

Molecular docking was then performed to determine where and how effectively each of the nine scFvs bind to the RAGE protein. The 3D structure files of the ectodomain and each of the scFvs were uploaded to the ClusPro server for molecular docking. For each of the nine RAGE-scFv docking assays, ten binding poses were visualized from most to least favorable depending on mathematically calculated interaction coefficients. For each assay, the complex with the best interaction coefficient, provided the respective scFv binds to the target druggable site, was selected for further analysis. If none of the ten poses involved binding in the druggable site, the respective scFv was eliminated from further analysis due to improper binding. To perform further analysis, the selected complex was inputted into the PRODIGY software to calculate its binding energy (ΔG) value in kcal/mol. A lower binding energy is optimal, indicating that the scFv and receptor bind strongly to one another (high binding affinity) and exert therapeutic effects. In addition to binding energy, molecular interactions and key interacting amino acids between each scFv and the RAGE ectodomain were determined using the PDBsum server.

The top two scFvs with the lowest binding energy and highest cluster size were subjected to molecular dynamics to determine time-dependent scFv-RAGE ectodomain stability over a period of multiple nanoseconds. A higher stability is preferred as it indicates the scFv will remain effectively bound to the RAGE ectodomain over time, necessary to exert anti-RAGE effects. Molecular dynamics (MD) simulations use computational modeling to determine the molecular movements of biomolecules like proteins within a dynamic timeframe and analyze parameters like stability and dynamic interactions over time (Aghajani et al., 2022). The GROMACS software was utilized to perform MD in a Windows Subsystem for Linux terminal environment, which includes two steps: (1) preparation run and (2) production run. In the preparation run, the AMBER ff14sb force field was utilized, and the complex was surrounded by TIP3P water molecules to mimic biological systems. To mimic the physiological ion concentration, the system was neutralized with 0.154 M Na^+ and Cl^- ions. The system was then energy minimized to remove unfavorable atomic clashes and equilibrated to stabilize temperature and pressure. Next, the production run (final MD run) was

performed for 10 ns at 2 fs timesteps. Once finished, the root mean square deviation (RMSD) and radius of gyration (Rg) counts over the 10 ns timeframe were tabulated in Excel and plotted into a line graph. RMSD and Rg variation throughout the simulation were determined by calculating the standard deviation of each. Lower RMSD and Rg fluctuations suggest the RAGE-scFv complexes are stable and at a low energy orientation, indicating optimal scFv performance.

In-Silico BBB Transmigration Assays:

In addition to molecular dynamics, the top two scFvs were subjected to molecular docking with ICAM-1 and VCAM-1, BBB adhesion proteins, to quantify their BBB transmigration potential. The blood brain barrier (BBB) is a complex network of endothelial cells that separates the blood and the brain. These endothelial cells contain numerous tight junctions that creates a tight seal blocking entry of most drugs and outside cells. Nonetheless, immune cells are known to effectively traverse the BBB by binding to specialized adhesion proteins via their integrin. Unlike typical immune cells, Treg cells naturally express lower or less activated integrins and therefore cannot bind to adhesion proteins like ICAM-1 and VCAM-1; this significantly restricts their ability to traverse the blood brain barrier. Designing BBB adhesion receptor-targeting scFvs compensates for this issue by providing an alternative method for BBB transmigration (other than via integrins), as these scFvs can also interact with BBB adhesion proteins. Thus, molecular docking was performed to determine if these scFvs can additionally bind to BBB adhesion proteins: ICAM-1 and VCAM-1. A binding affinity between -8 to -12 kcal/mol was favored, indicating it binds strong enough to initiate migration but not too strongly (below -12 kcal/mol) such that the Treg cell will not let go and enter the BBB (Klann et al., 2018).

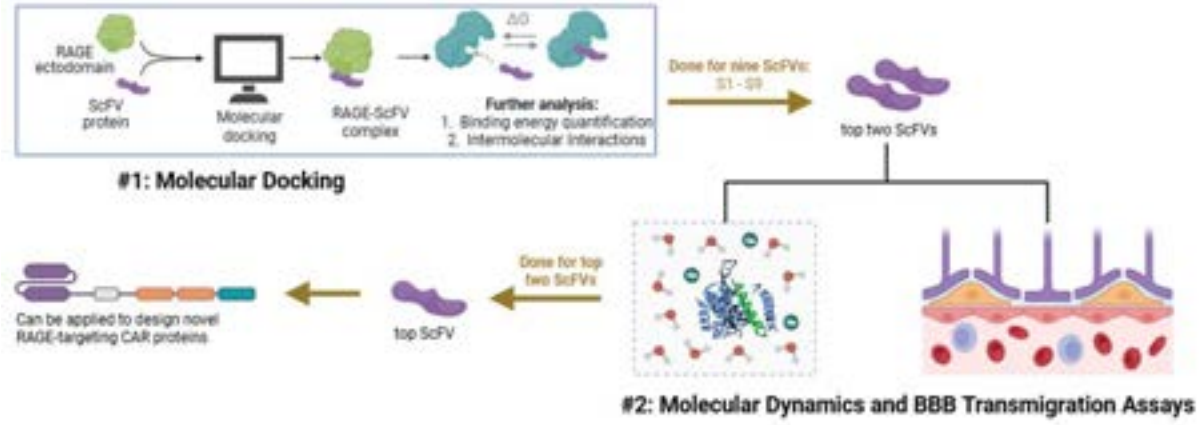


Figure 5. Visual workflow of methodology.

RESULTS

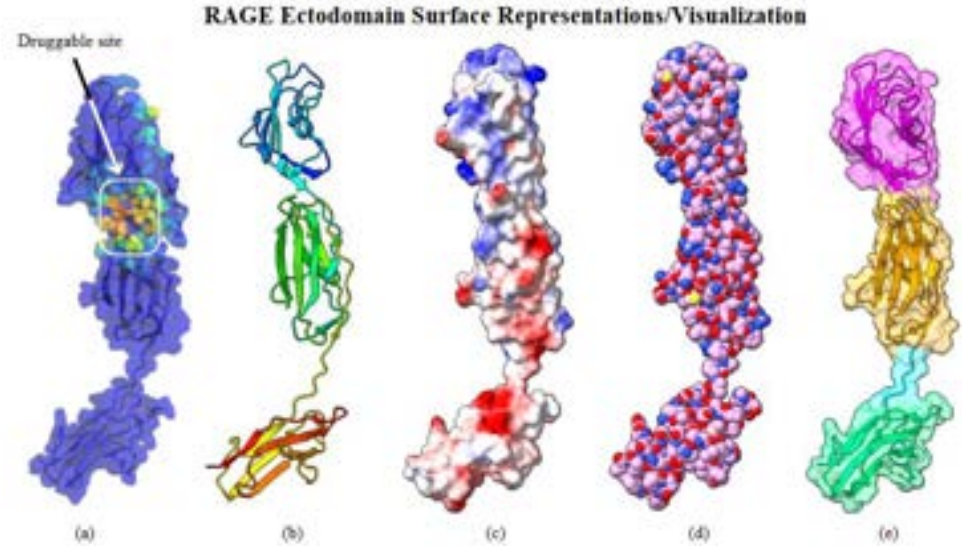


Figure 6. 3D visuals of the RAGE ectodomain: (a) Druggable binding site- orange and red regions indicate areas of high druggability; (b) rainbow coloring- blue represents the N-terminus (starting amino acids) of the protein sequence and red represents the C-terminus (ending amino acids) with a smooth rainbow gradient in between; (c) Electrostatic surface potential: blue denotes positive regions and red, negative areas; (d) space-filling model; (e) semi-transparent surface representation where magenta is the V domain, orange is the C1 region, cyan is the flexible linker region, green is the C2 region.

To elucidate the surface properties of the RAGE receptor protein, various visual representations of the receptor were created. Druggable site prediction was performed using the GrASP server to determine druggable areas of the RAGE ectodomain. A druggable binding site was revealed between the variable and C1 domains of RAGE. Additionally, various surface representations were created using ChimeraX: (1) rainbow coloring, which correlates the linear sequence of the protein to the final 3D structure that provides information about the mechanisms of protein folding; (2) electrostatic surface potential (ESP), which visualizes the charge of the protein surface; (3) space-filling model, which shows the individual atoms of the protein; (4) semi-transparent model. ESP visualization showed that the druggable site had a combo of positively charged and negatively charged amino acids, suggesting that ideal scFvs must carry a mixture of both charges to demonstrate optimal charge complementarity towards the druggable site.

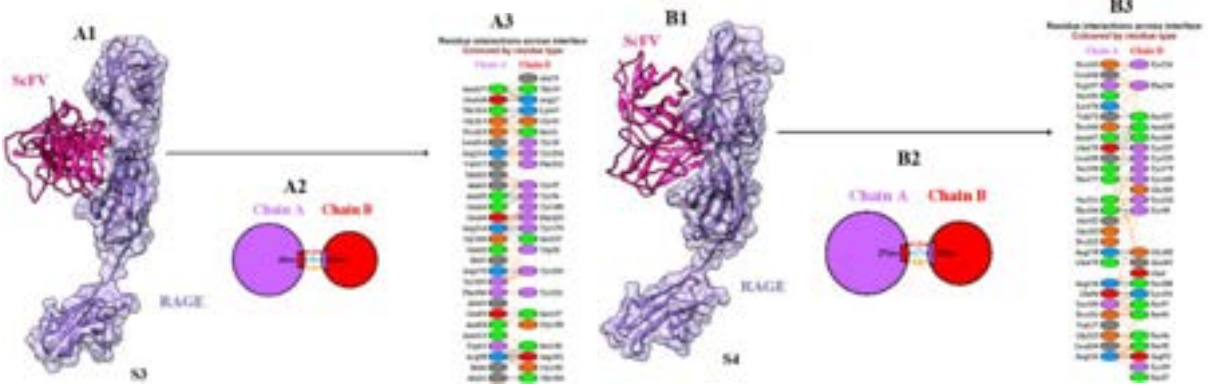
DiffAB designed a total of 9 candidate RAGE-targeting scFvs that were assessed for therapeutic potential. Molecular docking was performed to quantify binding energy between each of the scFvs (S1-S9) with the RAGE ectodomain, and the binding poses were visualized with ChimeraX (figure 2). All the scFv fragments except for S5 were included since S5 failed to bind to the target druggable site within RAGE, meaning it will not inhibit RAGE activity. scFvs S3 and S4 were chosen as the top two due to their strong binding affinities, as indicated by their low binding energy (ΔG) values: -17.4 and -12.8 kcal/mol. In addition to binding energy calculations, electrostatic interactions: salt bridges and hydrogen bonding between each scFv and the ectodomain were also determined. A direct correlation was revealed between binding strength and the number

of intermolecular interactions, where scFvs with strong binding had a lot more total interactions as opposed to those with lower binding energies. Electrostatic interactions are a lot stronger than neutral interactions like hydrophobic interactions and London dispersion forces (LDFs); thus, their abundance indicates strong affinity towards the RAGE ectodomain. Analysis of specific residues indicated an abundant presence of polar amino acids (Figure 7) like asparagine, threonine, and serine that facilitate formation of these electrostatic interactions.

scFv	H-bonds	Salt Bridges	Total	ΔG (kcal/mol)
S1	15	3	18	-11.4
S2	14	0	14	-10.7
S3	20	2	22	-17.4
S4	17	2	19	-12.8
S6	12	1	13	-10.3
S7	15	1	16	-10.2
S8	17	2	19	-11.7
S9	18	0	18	-9.3

Table 1. RAGE-scFv interactions and binding energy.

Figure 7. Binding poses of scFvs S1-S9 towards the RAGE ectodomain; purple = RAGE, pink = scFvs.



A. (B)

Figure 8. Interacting residues for (A) RAGE-S3 and (B) RAGE-S4 complexes.

Due to the superior performance of S3 and S4 in the docking phase, molecular dynamics were performed for the S3 & S4-ectodomain complexes. The standard deviation (SD) of each was calculated to determine variation. The RMSD variation (SD) values were 0.156 and 0.188 nm for S3 and S4, respectively, while the Rg variation (SD) values were 0.059 and 0.1177 nm, for S3 and S4, respectively. While RMSD variation was relatively similar along both scFv candidates with a slightly lower value for S3, Rg variation was significantly lower for the S3-ectodomain complex, showing that S3 forms a more stable, thermodynamically favorable complex with the RAGE ectodomain.

scFv	RMSD Variation	Rg Variation
S3	0.156 nm	0.059 nm
S4	0.188 nm	0.1177 nm

Table 2. RMSD and Rg variation over time for S3 and S4 scFvs.

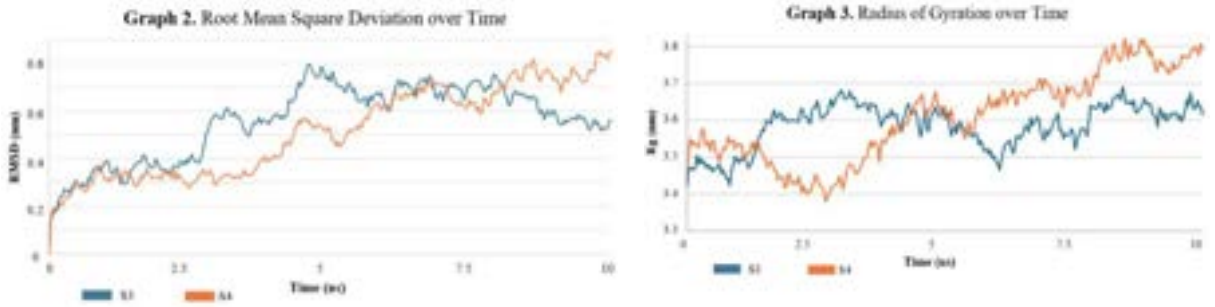


Figure 9. RMSD and Rg variation over time for S3 and S4 scFvs.

S3 and S4 were further subjected to molecular docking with BBB receptors: ICAM-1 and VCAM-1 receptors to analyze BBB transmigration. Both scFvs demonstrated optimal binding towards the VCAM-1 receptor. However, only S3 showcased optimal binding towards ICAM-1 as the S4-ICAM-1 complex had a binding energy below -12.6, indicating an excessively high binding strength. Therefore, S3 surpassed S4 in terms of BBB adhesion receptor binding and transmigration potential.

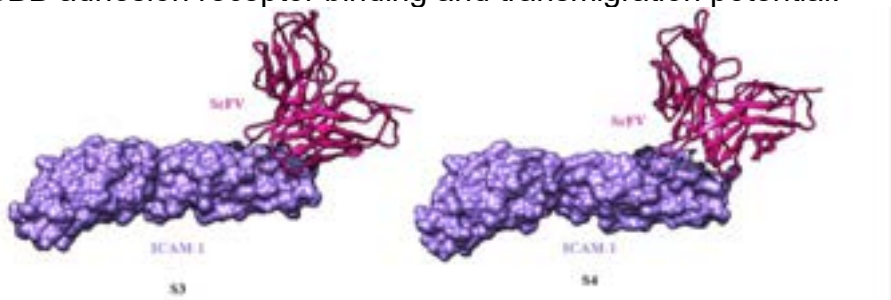


Figure 10. Binding poses of scFvs S3 and S4 towards the ICAM-1 BBB adhesion receptor.

scFv	Binding Strength to ICAM-1	Binding Strength to VCAM-1
S3	-9.8 kcal/mol	-11.2 kcal/mol
S4	-12.6 kcal/mol	-11.6 kcal/mol

Table 3. Binding affinity of scFvs S3 and S4 towards ICAM-1 and VCAM-1.

DISCUSSION/CONCLUSION

The primary goal of this study was to design novel scFvs that can effectively bind to the RAGE ectodomain and prevent pro-inflammatory M1 microglial phenotype acquisition. S3 and S4 were identified as the two best scFv candidates through molecular docking due to their low binding energies and favorable electrostatic interactions. Molecular dynamics simulations were performed for these two candidates to quantify stability via RMSD and Rg variation, and molecular docking with BBB adhesion receptors was performed to evaluate BBB transmigration potential. The results revealed that S3 possessed the lowest RMSD and Rg variation, indicating that it is most stable when bound to the RAGE receptor protein. Furthermore, S3 demonstrated more optimal binding towards both ICAM-1 and VCAM-1 BBB adhesion proteins than S4, indicating it can effectively squeeze through the BBB endothelium and enter the brain.

While research on RAGE-specific CAR Treg cell therapy has been minimal, numerous researchers have developed similar therapeutics for other proteins implicated in Alzheimer's and neurodegenerative diseases. For example, Saetzler et al. engineered novel CAR Tregs that target amyloid beta plaques, critical hallmarks of Alzheimer's disease through in-vitro and in-vivo techniques. It was revealed that the Aβ-specific CAR-Tregs were selectively activated by Aβ, maintained normal Treg cell anti-inflammatory characteristics, and inhibited CD8+ T-cells (equivalent substitutes for overactive M1 microglia). These results clearly suggest that the Aβ-targeting CAR Treg cells demonstrate potential for further testing with live microglial cell lines (Saetzler et al., 2023). Similarly, Frikeche et al. made novel CARs for Treg cell therapy that target myelin oligodendrocyte glycoprotein (MOG), a key antigen involved in multiple sclerosis, an autoimmune neurodegenerative disease. Through CAR activation assays, T-cell suppression assays, and autoimmune mouse models, it was shown that the CAR-Tregs demonstrated high selectivity for MOG and suppressed pro-inflammatory immune responses, demonstrating strong potential for multiple sclerosis treatment (Frikeche et al., 2024). Furthermore, Graber at al. engineered Tregs with hSOD1-targeting CAR proteins to prevent amyotrophic lateral sclerosis, a chronic neurodegenerative disease that destroys motor neurons (Graber et al, 2025). In summary, CAR Treg cell is a unique area of research with groundbreaking neuroscience discoveries.

Despite the robust findings of this research, the study still presents limitations that need to be addressed. First, many computational simulations and 3D structure prediction softwares rely on constant temperature and ion concentration. However, they often fluctuate under physiological settings, especially the human brain, thereby introducing potential errors in modelling protein-protein interactions. Additionally, the above results are heavily based on built-in algorithms and models used; inaccurate models may lead to false positives in molecular docking and molecular dynamics simulations. Due to these limitations, computational testing is only a baseline for drug design and not a replacement for clinical testing. For continued study, in-vitro binding assays like surface plasmon resonance and isothermal titration calorimetry can be conducted with co-cultured microglial and Treg cells to validate scFvs binding to CARs (Douzi, 2017). As the most prevalent neurodegenerative disorder, Alzheimer's plagues millions of individuals daily, causing slow, painful demises. The combination of computational and laboratory techniques can be applied to design effective scFvs and ultimately develop

high-output anti-Alzheimer's CAR Treg cell therapies to advance global healthcare and better society.

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Symposium 27 will be held at Potomac Shores Middle School on May 22, 2027.