

PROCEEDINGS OF THE **82ND** MEETING AND SYMPOSIUM



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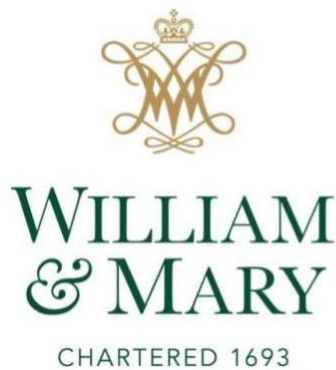


WILLIAM & MARY

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**Proceedings of the Virginia Junior Academy
of Science**

**Research Symposium and 82nd Annual
Meeting**



Proceedings of The Virginia Junior Academy of Science Virtual Research Symposium, hosted by
The College of William & Mary Williamsburg, Virginia

Edited by
Robin W. Curtis
Associate Director VJAS

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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 2021 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.

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 service.

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

May 5, 2023



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 82nd Virginia Junior Academy of Science (VJAS) Annual Meeting and Research Symposium. Although we are not able to meet in person, The College of William & Mary in Williamsburg, Virginia, is hosting our Research Symposium virtually this year.

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 virtual 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 82nd VJAS virtual Annual Meeting and Research Symposium is an enriching and engaging experience for everyone. Once again, welcome and congratulations on your accomplishments.

Sincerely,

Se W. Jeong
Chairman, VJAS Committee



George W. Jeffers Memorial Lecture

Friday Evening VJAS General Session

NASA's Search for Life Beyond the Earth

John Delano, PhD

Distinguished Professor (retired) University at Albany, State University of New York

John Delano received his PhD in geochemistry from Stony Brook University and retired in late 2016 from the University at Albany, State University of New York as a professor at the Distinguished rank. During his academic career, he served as the Associate Dean of the College of Arts and Sciences at the University, an Associate Director of a NASA Astrobiology Institute involving a consortium of five universities and was the recipient of several university awards including the President's Award for

Exemplary Public Engagement. He served on more than two dozen scientific advisory panels for both NASA and the National Science Foundation. His research was funded principally by NASA that resulted in 70 peer-reviewed articles in professional journals. Since arriving in Williamsburg, he has published two additional scientific papers, taught six courses for the Osher Institute for Lifelong Learning at William and Mary, and made more than 80 presentations to regional organizations.

Information Pertinent to the 2023 Virtual Meeting

2023 VJAS Paper Submissions and Acceptances (4/4/2023 DRAFT)

Category	Code	Level	Total Submitted (complete)	# DQed	Qualified Submissions	Acceptances	% of Qual. Accepted	Final % Accept (MaxAc/TotalSub)
Animal & Human Science	AH	MS	9	0	9	6	66.7	66.7
Chemical Science	CS	MS	22	0	22	19	86.4	86.4
Ecology & Earth Sciences	EE	MS	19	2	17	16	94.1	84.2
Engineering & Technology	ET	MS	15	2	13	13	100.0	86.7
Human Behavior	HB	MS	3	0	3	3	100.0	100.0
Math: Patterns & Relationships	MP	MS	1	0	1	1	100.0	100.0
Physical Science & Astronomy	PA	MS	5	0	5	5	100.0	100.0
Plant Sciences & Microbiology	PM	MS	29	0	29	26	89.7	89.7
TOTAL MIDDLE SCHOOL			103	4	99	89	89.9	86.4
Botany	BOT	HS	28	0	28	24	85.7	85.7
Chemistry	CHM	HS	31	3	28	25	89.3	80.6
Engineering	EGR	HS	40	1	39	35	89.7	87.5
Environmental Science	ENV	HS	73	2	70	61	87.0	83.3
Math: Theoretical & Modeling	MTM	HS	11	1	10	10	100.0	90.9
Medicine & Health	MDH	HS	66	3	63	49	77.8	74.2
Microbiology & Cell Biology	MCB	HS	37	0	37	35	94.6	94.6
Physics & Astronomy	PHY	HS	30	1	29	27	93.1	90.0
Psychology	PSY	HS	20	1	19	17	89.5	85.0
Statistical Analysis & Inferences	SAI	HS	15	0	15	13	86.7	86.7
Zoology	ZOO	HS	13	0	13	12	92.3	92.3
TOTAL HIGH SCHOOL			363	13	350	307	87.7	84.6
GRAND TOTAL			467	17	449	396	88.2	85.0

Middle School Sections

Animal & Human Sciences (MS AH)

First Place

Saanvi Sambangi-The Effect of different soaps on bacteria inhabiting the hand.
George H. Moody Middle School

Throughout the era of Covid 19, and when addressing the public in general, hand washing is arguably one of the most effective ways to rid oneself of bacteria. This is a process approved and highly recommended by the CDA for daily, individual practice. Additionally, it can rid the body of pathogens like E. coli, which can cause fatal liver failure, and stop people from developing severe skin infections. The simple task is the bare minimum in terms of hygiene and can prevent contagious annoyances such as common colds. The purpose of this experiment is to figure out which material, between bar soap, liquid soap, foam soap, and plain tap water, is the most effective at removing potentially harmful, or even mildly irritating pathogens. Afterwards, fifteen trials for each of the four independent variables were performed, using a stimulated bacterial gel and a U.V light. The stimulated bacteria were spread onto the hands and washed for 20 seconds using either foam soap, bar soap, liquid soap, or regular tap water. Following this, the U.V. light was shone on said hands and the amount of remaining mock microorganisms was recorded. The data was then averaged with a mean of 4.8 bacterial spots for bar soap, 7.2 bacterial spots for liquid soap, 6.5 bacterial spots for foam soaps, and 10.4 bacterial spots for tap water. Where foam soaps and liquid soaps ranked at similarly approximates, bar soap and tap water provided significantly different results. In accordance with the data, it is clearly indicated that bar soap was the optimal material to be utilized when cleansing the hands. Based on the information gathered through the trials, bar soap does seem to impact the bacteria far more than any other material tested. The hypothesis was not supported by the results, considering it was estimated prior that liquid soap would be the most effective. However, before the results can be officially put into practice, far more trials must be conducted in different situations in order to fully understand the effectiveness of handwashing soap.

Second Place

Ahana Goel-The Effect of Fennel Seeds on Pancreatic Cancer Cells
George H. Moody Middle School

Fennel (fennel seed) is a small greenish-brown seed belonging to the family *Umbelliferae* and is used in ayurveda to help with digestion (Krizman et al., 2007). They have many health benefits such as helping with clearing the skin, treating colic, keeps the liver healthy, and many more (Paul et al., 2021). Pancreatic cancer, or pancreatic adenocarcinoma, occurs when exocrine cells, which help transport enzymes throughout the body, start to change and crowd out normal cells. This cancer causes jaundice, bowel obstruction, appetite changes, etc (Stucky et al., 2021). The hypothesis was that if we use fennel seed extract on pancreatic cancer cells, then the growth of pancreatic cancer cells will decrease. The purpose of this experiment was to explore how well do fennel seeds actually work as a treatment. Although these seeds have a part in ayurveda, they aren't as well-known as other ayurveda medicines are. She wanted to see how well they worked. Two prepared plates containing twelve wells were ordered. In each well three slides of pancreatic cancer cells (provided by the VCU Molecular and Genetics Lab) were placed. In the second group of three wells of the first plate, 0.25 mg/ml of alcoholic fennel seed extract was placed. In the third group of three wells, 0.5 mg/ml of alcoholic fennel seed extract was placed and in the fourth group of three wells, 5 mg/ml of alcoholic fennel seed extract was placed. The same was done in the second plate with non-alcoholic fennel seed extract. After that, the cancer cells were violet stained with the fennel seed extract applied for 72 hours and the observations were recorded on the third day. Our results turned out to be that non-alcoholic fennel extract worked better than alcoholic fennel extract. The data supported the hypothesis because the hypothesis was that if fennel seed was used on pancreatic cancer cells, then the growth of the cancer cells would decrease. If the experimenter were to do this again, then she would add more trials in order to acquire more accurate results.

Third Place

Avery Shaw-The Effect of Yeast Types on the Taste of Root Beer
Sabot at Stony Point

This study looks at how different types of yeast affect the end product (a carbonated Root Beer) based on a blind taste by middle school students. There are many different types of yeast available for purchase, or that can be cultivated in the home. The yeast we used in this experiment were active dry yeast, wine yeast, champagne yeast, wild yeast, and beer yeast. We also used A&W root beer as our control group. This study attempted to determine if several commonly available yeast types would make a difference in the flavor of root beer based on student preference using a blind taste test. In order to conduct this experiment different bottles of root beer were created by adding different types of yeast to 2-liter bottles. The bottles had sugar,

root beer extract, water, and different yeast. This study determined that based on the middle school student's preference, after sampling root beer made by using 5 different types of yeast, as well as one root beer that is commercially produced, students preferred the commercial root beer and the root beer made with beer yeast. They disliked the active dry yeast and the champagne yeast. Over 50% of the students preferred commercial root beer. Ultimately, the study indicated that different types of yeast result in root beers with different flavors despite the other ingredients, and the fermentation process being the same. This study also indicates that root beer can be made in a non-commercial setting, and result in a flavor that is liked by middle school students.

Honorable Mention

Priya Kumar-The Effect of CBD oil on the Population of *Drosophila melanogaster*.
George H. Moody Middle School

Cannabidiol is a non-psychoactive compound found in the *Cannabis sativa* plant. It is known and marketed for its health benefits, but its safety has not been studied well. The purpose of the experiment was to study Cannabidiol's effect on the population of *Drosophila melanogaster*. The hypothesis of the experiment was, "If the *Drosophila melanogaster* is exposed to CBD oil, then the population of the *Drosophila* will decrease." The independent variable was the presence of a CBD/spring water mixture with a concentration of 1:100 in the starch media of the IV group. Both qualitative and quantitative data were collected, and proper safety precautions were used. The vials of the *Drosophila melanogaster* for the control and independent variable groups were visually examined on specific days based on the *Drosophila*'s life cycle to compare the number of eggs and larvae deposited by the flies. Photos were taken for documentation. From observation, the number of eggs, larvae, and flies in the control vials were greater than those in the IV vials. Also, after the removal of parent flies on day 8, the number of new flies were counted on day 15. The average number of flies in the control group was 48, and the average number of flies in the IV group was 24. This amounted to a 50% decrease. The quantitative and qualitative data obtained supported the experimenter's hypothesis. There was a substantial drop in *Drosophila melanogaster* population in the IV group compared to the control group. This study showed the potential toxicity of CBD oil. More research is needed to study the safety of CBD oil and its effect on various physiological systems.

Honorable Mention

Penelope Decker & Renna Thompson-The Efficiency of Clicker Training vs. Positive Reinforcement in Canine Training.

Sabot at Stony Point

For the experiment our objective was to determine whether or not clicker training was more effective than treat training. Two *Canis lupus familiaris*, one a miniature labradoodle and one a cavapoo, a clicker from amazon, two leashes, a polka *Canis lupus familiaris* treats two large water bowls, open space without the distraction of the field, and necessary tools. The *Canis lupus familiaris* were compared by how well they learned certain tricks from using a clicker or just treats. To conduct this experiment two *Canis lupus familiaris* were worked within an open grassy area. One *Canis lupus familiaris* was trained using a clicker, and one *Canis lupus familiaris* was trained using only treats. Order of training tasks was established. The order that the behaviors were taught to the *Canis lupus familiaris* were established to be loading the clicker, walking the length of board, going through a hoop, over a jump, and through a tunnel. Finally, these behaviors were linked together so the *Canis lupus familiaris* completed a chain of events. The results of the experiment indicated that both methods of training can be equally successful. This was determined by keeping a log of the time it took for the *Canis lupus familiaris* to learn different behaviors. Both *Canis lupus familiaris*, despite using different training methods were able to complete all the predetermined tricks and combine the tricks into a series of tricks. They were able to learn all the behaviors in the same training time period. In conclusion, the hypothesis that clicker training would be more successful was not supported by the results. It was also noted that the timing of the click and the timing that the treat was delivered to the *Canis lupus familiaris* was very important. Appropriate timing in the delivery was very important to the speed at which both canines were able to learn the behaviors.

Honorable Mention

Fin Byrne-The Eating Habits of an Invasive Species: The Cane Toad

Sabot at Stony Point

The process began by ordering the toad from an amphibian supplier. The right tank, living conditions, and suitable food sources were also obtained. After that, the process of data collecting started and from the data, it was acknowledged that when it came to mass, the toad ate more cat food, however, when it comes to amounts, the toad ate more crickets, considering four crickets were eaten. It was hypothesized that natural

food, such as mealworms or crickets would be the preferred food of the Cane Toad. However, the final results indicated that non-natural foods, such as cat food, as indicated by the results, were the preferred foods based on mass. The food choices of Cane Toads is of special environmental importance as they are a noted invasive species in many places, and having a negative impact on native wildlife and food chains. Cane Toads are toxic if eaten and negatively impact the population of native predators. If preferred food sources can be determined, then natural and humane alternatives to control the invasiveness of Cane Toads can be further explored.

Chemical Science A (MS CS-A)

First Place

Shravan Madurantakam -The Effect of Crosslinking on Diffusion of Robitussin™ from Calcium Alginate Gel.
George H. Moody Middle School

Softgels are one of the most popular forms of orally administered medications due to its ability to carry a variety of drugs, ease of swallowing as well as faster action. Animal-derived gelatin is the main ingredient in softgels but is not a viable option for some people due to allergies, religious beliefs, and lifestyle choices. The goal of the study was to use calcium alginate gel as an alternative to gelatin softgel to carry Robitussin™. The study hypothesis was the longer the sodium alginate homogeneous mixture remained in the calcium chloride solution the less permeable the gels would become. Food grade sodium alginate (2g) and Robitussin™ (2.5ml) was dissolved in 250ml of water to make a colloid. Calcium chloride solution was prepared separately (2g in 250ml). Equal volumes (1ml) of colloid and calcium chloride were added to the wells of the 12-well plate and allowed to react for 10min, 3hr., 6hr. and 24hr. time points (independent variable). Each time point had 10 trials. The reaction was stopped at designated times by removing calcium chloride and rinsing gels with water. Clean gels were then incubated with 1ml of lemon juice (pH 3) for 2 hours to mimic the pH of the stomach. After 2 hours, the solution was transferred into a new plate and photographed. The images were quantified using ImageJ for the color saturation (dependent variable) and the saturation numbers across groups were statistically analyzed using JMP software. Statistical differences between various groups were present. These included the 10 min group being statistically different from the 3 hr. and 6 hr. groups as well as the 3-hr. group being statistically different from the 24-hr. group. The data from the experiment did not correspond with my original hypothesis.

Second Place

Kota Karthikeya-The Effect of Sunscreen on Saccharomyces cerevisiae to Prevent Ultraviolet Radiation
George H. Moody Middle School

Sunscreen is a vital protective agent against the harmful rays of the sun, safeguarding the skin from the effects of both ultraviolet A and B radiation. In this study, I investigated the effects of different sunscreens on the growth of yeast cells exposed to ultraviolet light. Yeast cells are single-celled fungi that produce alcohol and carbon dioxide through fermentation. Exposure to ultraviolet light can lead to mutations in yeast cells, which

can prevent DNA repair and result in cell death. The objective was to determine if the use of sunscreen could prevent or reduce the death of yeast cells under ultraviolet light. I prepared a yeast solution by mixing 2.5 teaspoons of active dry yeast, 1 teaspoon of granulated sugar, and warm water at 43 degrees Celsius. One milliliter of the solution was then evenly spread across agar Petri dishes. Six Petri dishes were used in the experiment: the control dish, SPF 15 dish, SPF 50 dish, sun dish, cotton dish, and polyester dish. The top of the SPF 15 and 50 dishes were covered with the respective sunscreens, and the sun dish was directly exposed to sunlight. The results showed that the control dish had around 75 countable colonies, while no countable colonies were observed in the sun dish. The SPF 15 and 50 dishes had 30 and 60 colonies, respectively, and the cotton and polyester dishes had 10 and 25 colonies, respectively. This study suggests that sunscreen can be effective in protecting yeast cells up to 50% concentration, and higher concentrations of sunscreen can inhibit growth. These findings are consistent with our hypothesis that sunscreen can protect yeast cells from ultraviolet light.

Third Place

Brandon Bedestani & Abbott Logan-The Effect of Type of Chip on the Amount of Fat
Dorothy Hamm Middle School

With the rising obesity rates in the United States of America, identifying the primary contributors to weight gain is a key point of interest for individuals seeking to improve their health through targeted intervention strategies. This experiment hypothesized that snacks with increased use and exposure to oil in the cooking process would result in a higher fat content; therefore, choosing snacks with reduced oil use and exposure in the cooking process would result in a healthier food option. This experiment focused on four commonly consumed snacks, including Lay's Brand Potato Chips, Harvest Snaps Pea Crisps, Snyder's of Hanover's Lightly Salted Pretzels, and Mission Corn Tortilla Chips. This experiment hypothesized that Lays' Brand Potato Chips would have the highest concentration of fat because the cooking process requires the most intense amount of frying. For this experiment, acetone was used to extract the fat from the chips, as acetone is a very strong chemical that attaches to fat and supports a separation from the food. Chips were crushed, divided into individual containers, and labeled. Then the acetone was used to extract the fat through a process of combination then filtration. Once the acetone boiled off, the fat remained in the container. The fat was measured and compared among each sampled chip. The results of this experiment indicated that the hypothesis was correct – Lay's Brand Potato Chips have the highest concentration of fat due to the cooking process requiring the most significant use and exposure to oil.

Honorable Mention

Ritvik Adusumilli-The Effect of Different Household Chemicals on the Corrosion Rate of Stainless Steel.
George H. Moody Middle School

This study was to prove how the salinity of a chemical corrodes stainless steel. Following, the purpose of the study was to find out ways to prevent appliances and other daily and necessary stainless-steel objects from damage and corrosion. The researcher simulates this corrosion process by using fifty Type 304 stainless steel cups and submerging them in the levels of IV, of the household chemical factor, which are lemon juice, vinegar, baking soda, soapy water, and the control water. In a seven and a half-day experiment, the experimenter weighs and concludes the data for this experiment. From there the study continues, the researcher calculating whether the results were accurate and if the hypothesis, "If the household chemical has a high sodium concentration or has high salinity, then the stainless steel (DV) corrosion process will increase in rate" was true or false. The evidence then points to baking soda, the chemical that contained the highest sodium, sodium chloride content, having the highest rate of corrosion. The hypothesis was then proven correct. The findings relate to many other types of research, 3rd party examinations, and more. The chemicals had broken through the outer layering of wax of the stainless steel, and the sodium content would be the major factor in the corrosion of the stainless-steel cups, the DV of the experiment. The hypothesis was also backed up, as water, one of the least corroding chemicals in the experiment, had the lowest salinity. In conclusion, the experiment was a study to find the effects of salinity on the corrosion rate of a common metal known as stainless steel. The purpose of the experiment was to find out what can be done to protect the longer-used stainless steel appliances.

Honorable Mention

Abby Knepper-The Effect of the Healthy Glucose Replacements on the Height of the Candy
Williamsburg Middle School

The question that is being answered through this experiment is what a healthy replacement for glucose in candy is that has the closest height to the original candy. Glucose syrup, also known as confectioner's glucose, is a syrup commonly used as a sweetener in food production. The problem with it though is that it isn't very healthy. The purpose of this project is to find out how to make things with glucose syrup (some candies, as an example), to be healthier, yet looking the same as the original candy. That is why height was chosen to be measured, because it can affect the appearance and make the candy look different compared to the original.

Glucose syrup is made from the breaking down of starch through hydrolysis. Hydrolysis is the chemical breakdown of a compound due to its reaction with water (Morgenroth, 2002). That is what releases the glucose units. 3 different trials were tested at each level, and the levels were agave nectar, honey, and extra sugar. There was also a control level, which was glucose syrup, where 3 trials were conducted. The data was collected in figure A, and graphed in figure B. The results were that the honey had the closest height to the control, while the extra sugar had the least similar height. This went against the hypothesis, where it was thought that the honey would have the least similar height because of its percentage of glucose. However, all of the trials crystallized, causing all of them to have a cloudy and opaque look, while the control was translucent. So, it was concluded that the honey replacement would be the best, but not a perfect replacement.

Honorable Mention

Prithvi Chakraborty-The Effect of Enzyme Invertase on Glucose Concentration Level

George H. Moody Middle School

Around the world, over 415 million people have diabetes, and these individuals have to maintain healthy glucose levels to prevent the unpleasant symptoms of conditions such as hyperglycemia and hypoglycemia. By turning sucrose into glucose, the enzyme invertase mimics one of the chemical reactions that occur during digestion, and glucose is a simple type of sugar that is gotten from the foods and drinks an individual consumes. The purpose of this experiment was to determine the effect the enzyme invertase had on glucose concentration levels in drinks. The researcher's hypothesis is that if the enzyme invertase is added to a drink, then the glucose levels will rise because sucrose will convert into fructose and glucose, and Sunkist, specifically, will have the highest glucose concentration level because it has the most calories/sugar. For each level of the independent variable or each drink, using a graduated cylinder, the researcher poured 15 milliliters of each drink into a labeled disposable plastic cup. Next, the researcher took a sample of the drink's glucose level to determine the amount of glucose already present. After that, the researcher added 0.5 milliliters of invertase using a pipette to the 15 milliliters of the drink and waited 35 minutes using a stopwatch, which was the linear time point. The researcher repeated these steps 10 times for each drink and recorded new glucose measurements using a glucose test strip. Sunkist had the greatest initial increase in glucose concentration level and water had a 0% initial and after glucose concentration level as there was no sucrose present in the drink. The results indicated that the higher the sucrose was present in the drink, the greater the glucose concentration level of the drinks was. The researcher's hypothesis was supported and by calculating the

amount of glucose in a drink, it can determine which drinks are acceptable to take in moderation while maintaining a healthy blood sugar level and which are not.

Shayna Becker & Julia Murray-The Effect of Sugar Content on the Evaporation Rate of Liquids
Sabot at Stony Point

The purpose of this experiment was to determine the evaporation rates of different liquids based on their sugar content. To determine how sugar content affects different liquids, ten different common beverages were selected, including some beverages with no sugar content (water and diet coke). The different liquids were put in petri dishes and exposed to the same temperature and pressure over the course of a week and a half. The mass of the liquids was measured to determine the rate of evaporation. It was hypothesized that if a liquid is less dense and has fewer sugar molecules dissolved in the liquid it will evaporate more rapidly because there are fewer molecules to evaporate. The results showed that liquids with a higher sugar content will not evaporate fully and will end with a higher mass in the end.

Kalagi Shrihari The Effect of Household Acids on the Rate of Corrosion
George H. Moody Middle School

Corrosion of steel wool and metals is a massive problem for many people across the globe. Metals and steel wool that are not treated with proper care, once they start corroding, may eventually become unusable for humans. If an acid is lower on the pH scale, then it is more acidic and therefore more harmful to buildings. For these reasons, this project was conducted to find the worst drinks for people to apply to man-made structures. This experiment was conducted with the hopes of helping people care more about their surroundings and to help them understand the harmful effects of various household liquids. The hypothesis made was that if Tamarind Water is used, then the steel wool will heat up the most. Ultimately, the experiment was declared finished. This entire procedure was then repeated nine more times. Lemon Juice clearly performed the worst with an average increase in temperature of 7.78 degrees Fahrenheit. With this statistic, it was proven that the hypothesis was not supported. The findings of this experiment can be supported by the fact that the different liquids had different kinds of acids in them, so they all had various capabilities. Since, all of the independent variables had acidic characteristics, except the control, water, they were all able to successfully corrode the samples, but they each accomplished this at different speeds and amounts. A problem that could be solved

is that there should be a more effective way of recording the rate of corrosion over periods of time for each sample. An effective way to solve this problem would be to record the temperatures of the steel wool should every few minutes, instead of all of them getting recorded once at the end.

Diyaa Kirubaharan-The Effect of Different Foods on Stomach Acids
George H. Moody Middle School

The motivation behind this trial was to see which food best helps reduce an acidic stomach. The foods used were lemon water, baking soda, oatmeal, and bananas. Lemon's pH ranges from 2 to 3, making it the citrus fruit with the highest pH. Baking soda is an alkaline substance that neutralizes stomach acids. Bananas contain lots of pectin and fiber, which also neutralizes the stomach. Due to oatmeal's high fiber content, it promotes regular bowel motions and keeps you feeling fuller for longer. The researcher's hypothesis was if the baking soda is left in the white vinegar for three days, then the acidity of the white vinegar will reduce more than the oatmeal, banana, and lemon water. Baking soda reduced the pH of the white vinegar the most and the fastest. The initial pH of the white vinegar ranged between 3 and 4. The pH immediately after the baking soda was 6.4, and after three days, the pH was 6.2. After three days, the banana, with a final pH of 5, and the lemon water, with a pH of 4, were the two things that had the least impact on neutralizing the white vinegar. The lemon water, with an initial average pH of 3.5 and a final pH of 4, had the least impact on all the foods. The hypothesis was supported by the data collected.

Chemical Science B (MS CS-B)

First Place

Ishan Shah-Comparing the Solubility of Brand vs Generic Allergy Medications in Hydrochloric Acid with pH similar to Stomach Acid.

George H. Moody Middle School

Seasonal as well as perennial allergies are the sixth leading cause of chronic illness in the US. Allergies pose a significant burden on the healthcare costs every year in the US. The cost of nasal allergies is between \$3 billion and \$4 billion each year, while food allergies cost about \$25 billion each year to the US healthcare system. The most common medications available in the U.S. to treat allergic reactions are antihistamines like Claritin, Zyrtec, Allegra, and Benadryl. Each of these medications are available in several generic forms in different stores. Since generic medications contain the same active ingredient as the brand name medication, the inactive ingredients contained in the generic medications can cause a change in the solubility of the medication in stomach acid and thus its onset of action can be different as compared to the brand name medication. The onset of action of an allergy medication is critical to its effect since a delay in onset of action can cause an allergic reaction and therefore allergic symptoms in the patient. The purpose of this study was to compare the solubility of different generic medications from four different drug stores with their respective brand name medication. The brand name allergy medications used in this study were Claritin, Zyrtec, Allegra, and Benadryl. This study showed that the different brands of allergy medications had different solubility times in hydrochloric acid with pH 2 which simulated stomach acid in this study. There were also significant differences in the solubility times of brand name medications and generics from different stores. This study also showed that generics from Walgreens drug store consistently showed lower times for complete solubility and thus earlier onset of action for the drug effect as compared to other generics. This study also showed that Allegra and Benadryl had a much lower time for complete dissolution in HCl with pH 2 as compared to Claritin and Zyrtec and thus a much quicker onset of action.

Second Place

Essam Shah – The Effect of the Filtration Efficacies Among Dissimilar Semi-Permeable Fabric Types on Air Decontamination.

George H. Moody Middle School

Toxic particulate matter widely roams the atmosphere, posing a global biohazard as microscopic pollutants and viral particles incessantly encompass the Earth. Various technologies were introduced to the global public to counter the repercussions of viral or pollutant inhalation, such as masks, yet they are inaccessible due to soaring demands during the Coronavirus pandemic. Common fabrics may serve as an optimal alternative for masks, serving as the inspiration for this investigation. The intention was to determine which common fabric of Cotton, Fleece, Wool, and Rayon possessed the strongest filtration efficacy, and it was hypothesized that Cotton would statistically surpass that of the other semi-permeable fabrics. To recapitulate the procedure, a box featuring an internal vacuum device from which the chosen fabric was screwed to the mouth hosted the investigation, surmounting a particle counting device to its side. For each thirty-second trial, a teaspoon of Aluminum Oxide ultrafine powder was deposited into the box and remained flowing due to the airstream an internal fan produced. The aspiration was to determine the amount of particulate (PM 2.5) micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) the chosen filter would occlude, as the device could measure only airborne particles, neglecting grounded and occluded matter. The results of such an investigation yielded that the hypothesis was narrowly supported, as Cotton slightly surpassed its competitors by a diminutive margin as only a mean of $41 \mu\text{g}/\text{m}^3$ particles remained. Rayon demonstrated the poorest filtration efficacy as a mean of $50 \mu\text{g}/\text{m}^3$ particles remained. Additionally, the P-values for each pair of fabrics were recorded and analyzed, deeming the majority of tests conducted as statistically significant, while proving that Wool may indirectly rival Cotton according to the abnormally high P-values, also revealing the presence of error in the experiment. The few other investigations associated with the topic supported such results, and the sources for sources were minimal and anticipated. Individuals should evade materials such as or associated with Rayon or Wool and opt for surfaces such as Cotton and Fleece when constructing alternative masks.

Third Place

Lydia Tuchinsky-The Effect of Different Liquids on Copper Tape

Dorothy Hamm Middle School

Copper has been used for thousands of years because of its ease of manufacturing and its reliability. However, there have been pinhole leak problems in copper pipes throughout the country. Previously, there was little knowledge about why this was happening; this experiment examines if liquid household chemicals might be a reason for some of the leaks. Seven common liquid household chemicals were placed in plastic cups with strips of copper tape along the side and bottom of each cup. In general, the basic liquids had stronger chemical reactions than the acidic liquids when interacting with copper. Chlorine bleach dissolved the copper that was

submerged in the solution and formed black crystals (cupric oxide). Liquid ammonia mostly dissolved the copper and formed blue crystals (cupric nitrate). A baking soda (sodium bicarbonate) solution formed green crystals (cupric carbonate). These color changes meant reactions were occurring, as all looked quite different than the original red brown copper color. The copper that was submerged in the acid solutions retained its nominal reddish color, except for when it turned pinker. This experiment shows that it is not advisable to pour large amounts of liquid chlorine bleach down a copper drain, or into other types of copper plumbing. Public water systems should take this into consideration as they chlorinate the public water supply to prevent widespread plumbing issues.

Honorable Mention

Advika Mahesh-The Effect of Heat Cooking Methods on the Rate of Degradation of Ascorbic Acid in Bell Peppers

George H. Moody Middle School

Vitamin C (also chemically known as Ascorbic acid) is one of the vital nutrients needed for the growth and development of the human body. However, we generally receive lesser amounts of vitamin C from the food we consume given that it is a nutrient that is highly sensitive to several factors including heat and moisture and gets destroyed during food processing. The present study evaluates how different heat cooking methods affect the degradation of vitamin C in red bell peppers – a vegetable that contains more vit C than popular citrus fruits such as oranges. The study evaluated four different commonly used kitchen cooking methods – Sauteing, Microwaving, Boiling, and Steaming at different cooking time intervals and the overall hypothesis was that the group 25tyrofong the highest amount o– moisture and heat as a function of time would result in the maximum loss of ascorbic acid. Six Sunset red bell peppers were each diced into smaller cubes and subjected to all the four cooking methods including an unprocessed Control to determine the ascorbic acid content before cooking. Three-time intervals for each food processing treatment were also selected based on the final quality of the cooked bell pepper as typically observed in prepared foods. Ascorbic acid analysis was conducted using the indophenol reagent titration method and significance of loss was statistically evaluated using a Standard T-test. The results indicated that the sauteing treatment had the greatest rate of degradation of ascorbic acid in the red bell peppers with a maximum observed mean loss of 36% compared to all the treatments. In general, Microwaving was the best rapid heat cooking method with a least observed loss of 14% at the maximum time of 3 minutes tested. The data did not fully support the research hypothesis and the current findings recommend that temperature control is more critical to minimize the rate of degradation and

overall loss of ascorbic acid in red bell peppers followed by cooking time and amount of moisture.

Honorable Mention

Risvan Ramkumar-The Effect of Temperature on the Corrosion of Aluminum
George H. Moody Middle School

This research paper investigates the effect of temperature on the corrosion of aluminum. The paper begins by introducing aluminum as a lightweight, strong, and versatile metal used in various industries. Corrosion is defined as the natural conversion of refined metal to a more stable form, leading to material deterioration. Although aluminum is naturally resistant to corrosion, it can still corrode in certain environments, causing damage to metal structures. The paper then describes the types of corrosion that can occur, such as pitting corrosion, crevice corrosion, galvanic corrosion, and stress corrosion cracking, and how they can be prevented using protective coatings. The investigation involved immersing an aluminum plate in a salt solution at different temperatures and observing the formation of rust on the surface of the plate. The hypothesis was that if the solution of higher heat is applied, then the aluminum plate will corrode. Ferric chloride and sodium were added to the solution to induce pitting corrosion in alloys and increase the rate of oxidation corrosion, respectively. Safety precautions were taken, and the experiment was conducted for a period of five days. The results showed that the aluminum plate exposed to temperatures above 60°C began to corrode, supporting the hypothesis. The findings suggest that understanding the corrosion process and the factors that contribute to it can help communities take steps to protect their metal structures from corrosion. Overall, the study highlights the importance of preventing corrosion to ensure the safety and longevity of metal structures.

Honorable Mention

Caroline Sundberg-Which Types of Fabric (Linen, Felted Wool, or Polyester) will Dye the Most Effective in Different Types of Water.
Sabot at Stony Point

The purpose of this experiment was to test how when three different types of fibers. And also, two different types of water affect the overall concentration of the dye and saturation of the fibers. Three different fibers were put in two dye baths made up of the same dye but using different water types. Each type of fiber was kept in each dye bath for 15 minutes and then taken out and left to air dry. Once dry, a color wheel from white (one) to navy blue (twelve) was used to measure the darkness of each color. Google sheets was used to chart

the data and turn it into a Column Chart as well. It was hypothesized that the wool fiber in the tap water would have the darkest overall dye because tap water was not carbonated. The results ended up with the Linen and Wool fibers in the sparkling water having the darkest shade. The polyester fiber in the tap water had the lightest shade. None of the overall dye scores exceeded twelve, but there were none lower than four. All of the higher dye scores were from the natural fibers, and all of the lower dye scores were from synthetic fibers.

Kate Marino-The Effect of Cooking Style on how much Vitamin C is Preserved in Broccoli
Williamsburg Middle School

The rationale of this experiment was to determine the effect of cooking style on how much Vitamin C is preserved in broccoli. Research has shown that Vitamin C is water soluble which makes them more susceptible to loss during the cooking process (Ana Soares et al, 2017). Vitamin C is crucial for human health and needs to be replenished often. The amount of Vitamin C preserved, based on cooking style, is essential when determining the best cooking style to use in order to preserve the most amount of Vitamin C. In this experiment, an iodine and starch method were used. What was observed was the amount of Vitamin C present in the broccoli after being cooked with iodine and starch. After the blue color from the iodine in the solution persisted, the amount was recorded. The experiment was conducted three times. The broccoli was microwaved, boiled, and steamed. The same amount of broccoli and water was used. The hypothesis – that if the broccoli is boiled then there will be less Vitamin C preserved – was supported; the boiled broccoli had the least amount of Vitamin C preserved compared to the other two cooking styles. The cooking style that preserved the most amount of Vitamin C overall was steaming. The second-best cooking style that preserved Vitamin C was microwaving it.

Spencer Massie-What Corrosion Inhibitor slows the Rusting of Iron the most effectively?
Sabot at Stony Point

The purpose of this investigation was to find what commercially available chemical slows rusting the most in iron (Fe). Rusting occurs when a metal (ie. Iron) is exposed to moisture and oxygen. The process happens faster when the temperature of the air is higher or the moisture and oxygen in the air are increased. In order to carry out this investigation, iron cubes were thoroughly coated in rust-preventing chemicals, which were in turn doused in a salinated hydrogen peroxide solution. The efficacy of the chemicals was determined by

measuring the mass (in grams) of the iron cubes before and after the dousing of the hydrogen peroxide solution. The amount of mass lost was then divided by the time in hours that the cubes were left with the solution. It was determined that level 1, STA-BIL rust stopper, was the most efficient at slowing rust with an average of 0.032 grams lost per hour, compared to 0.033 grams/hour for CRC Corrosion Inhibitor and 0.0335 for CorrosionX. The control variable lost the least amount of mass per hour, with 0.0043 grams/hour. Overall, rust inhibitors did not slow the rate of the rusting of iron when compared to a cube that was not coated in a rust-inhibiting chemical. This study indicates that corrosion-inhibiting chemicals would not be beneficial to companies and individuals who are seeking to reduce the loss of ferrous commodities and reduce the negative financial and aesthetic impact caused by rust because the unaltered metal cube had the least amount of rusting per hour.

Aditya Purohit-The Effect of varied Antioxidants and Microbials on food Deterioration
George H. Moody Middle School

Throughout generations, chemicals, and organic materials such as vinegar, sodium chloride, sulfuric acid, and glucose have been used to preserve food in varied civilizations around the world. Whereas as of today, these preservative methods are utilized but are altered in ways that can harm humans throughout the world and cause food poisoning diseases. Therefore, to investigate healthy preservatives and the chemical composition being manipulated due to the additives, the experiment is conducted over the effect of varied antioxidants and antimicrobials on food deterioration.

Ecology & Earth Sciences A (MS EE-A)

First Place

Barathi Saravanan-The Effect of Different Natural Plasticizers on the Biodegradability and Water Solubility of Cornstarch Plastic Films

George H. Moody Middle School

Plastic is a material that has become an essential part of peoples' lives after its discovery in 1907. However, the production and utilization of plastic has a detrimental impact on the Earth. Many alternatives have been found, but they are expensive to produce and are inaccessible in many areas. One possible solution that is gaining support is bioplastics. These are plastics that release less greenhouse gasses and are biodegradable. The aim of this experiment is to find out which natural plasticizer results in bioplastic with plastic-like physical behavior along with biodegradability and water solubility. The hypothesis of this experiment was that if the bioplastic has glycerin as the plasticizer, then it would degrade faster and have the highest water solubility. The control of the experiment is commercial plastic, and the independent variables are natural plasticizers like glycerin, sesame oil, coconut oil, and castor oil. Bioplastic was prepared by the gelatinization of a slurry of cornstarch and various plasticizers in distilled water. The experiment was repeated ten times and the mean values are used in the results. Biodegradability of developed bioplastics was observed by soil burial method. Similarly, water solubility was measured by immersion of bioplastics in water. The results obtained disproved the researcher's hypothesis because the sesame oil plastic degraded the most (2g to 0.6g) and the castor oil plastic absorbed water the most (2g to 5.6g). Although bioplastic with sesame oil has highest biodegradability, it was highly brittle. The plasticity in terms of having the capability to be sturdy and foldable was found to be good in bioplastic with glycerin. It was thus concluded that glycerin is best for bioplastics even though it wasn't the fastest to degrade. In addition, glycerin is accessible and can be found in almost every grocery store. Although oils that were used as plasticizers were brittle and broke easily, it was found after further research that they could be malleable if made through polymerization.

Second Place

Aarya Karmarkar-The Effect of Fertilizer on Water Quality

George H. Moody Middle School

Water quality has become an important issue that could have a long-term effect on the health of human beings and the environment at large. One of the primary causes of water pollution is the application of fertilizers to residential and commercial landscapes. The overarching effects of these products that are being used to keep lawns green, on the ecosystem include deterioration of overall water quality that can affect the health of humans, animals and plants alike, and result in the excessive growth of harmful algae. This experiment explored the effects of different types of fertilizer on water quality. Four tanks of equal dimensions were filled up with 35 liters of water. An equal or equivalent amount of each of three different types of fertilizer – organic, inorganic, and manure, was added to each of three out of a total of four tanks, and these tanks were labeled accordingly. The fourth tank was not treated with any fertilizer, and this served as the control group. At baseline, 3 days, 7 days, and 10 days, the water quality for each of the tanks was tested using a commercially available water testing kit. The kit measured free chlorine, iron, copper, lead, nitrate, nitrite, total chlorine, fluoride, cont. The results were derived using the average of the three rounds of experiments for each of the four groups of the independent variable, the levels of which were Control group, Manure group, Organic Fertilizer, and Inorganic Fertilizer. The researcher hypothesized that the aquarium tank with the organic fertilizer will have the water quality results closest to that in the Control group as compared to the other two fertilizer variations. Some major experimental research findings were contradictory to the researcher's hypothesis. Even though organic fertilizer contains less nitrogen than the other types of fertilizers used, the overall pH level as well as the increase in the pH level from baseline was the highest for the Organic group compared to the increase in the pH levels in the other two fertilizer groups.

Third Place

Siddharth Ghosh-The Effect of APS Schools on Stormwater Quality
Williamsburg Middle School

Water quality has become an important issue that could have a long-term effect on the health of human beings and the environment at large. One of the primary causes of water pollution is the application of fertilizers to residential and commercial landscapes. The overarching effects of these products that are being used to keep lawns green, on the ecosystem include deterioration of overall water quality that can affect the health of humans, animals and plants alike, and result in the excessive growth of harmful algae. This experiment explored the effects of different types of fertilizer on water quality. Four tanks of equal dimensions were filled up with 35 liters of water. An equal or equivalent amount of each of three different types of fertilizer – organic, inorganic, and manure, was added to each of three out of a total of four tanks, and these tanks

were labeled accordingly. The fourth tank was not treated with any fertilizer, and this served as the control group. At baseline, 3 days, 7 days, and 10 days, the water quality for each of the tanks was tested using a commercially available water testing kit. The kit measured free chlorine, iron, copper, lead, nitrate, nitrite, total chlorine, fluoride, cont. The results were derived using the average of the three rounds of experiments for each of the four groups of the independent variable, the levels of which were Control group, Manure group, Organic Fertilizer, and Inorganic Fertilizer. The researcher hypothesized that the aquarium tank with the organic fertilizer will have the water quality results closest to that in the Control group as compared to the other two fertilizer variations. Some major experimental research findings were contradictory to the researcher's hypothesis. Even though organic fertilizer contains less nitrogen than the other types of fertilizers used, the overall pH level as well as the increase in the pH level from baseline was the highest for the Organic group compared to the increase in the pH levels in the other two fertilizer groups.

Honorable Mention

Daisy Bell-The Effect of Radiation on Seed Germination
Dorothy Hamm Middle School

Many countries have been affected by electromagnetic radiation. The purpose of this experiment was to figure out if it was possible to grow plants, specifically cress seeds, after they have been irradiated. Five different sets of seeds were microwaved a distinctive amount of time (0, 5, 10, 20, and 40 seconds). Each was put in a container filled with soil and then spritzed with water. The number of seeds germinated was logged. 35% of the seeds germinated in the control group, 25% percent of seeds germinated from the 5-second group, 10% percent of the seeds germinated from the 10-second group. 0% of the seeds germinated from the 20- and 40-second groups. In summary, small amounts of radiation have little effect on seed germination, but greater amounts of radiation do have a greater effect on the number of seeds germinated.

Honorable Mention

Egshiglen Ganbat-The Effect of Soil pH on the pH of Water
Dorothy Hamm Middle School

Soil may have an impact on the quality of water for human consumption. Small levels of soil help clean and kill harmful bacteria, making water safe to drink. However, high levels of soil in water can cause poor drinking

water quality, loss of water supply, high cleanup costs, and/or potential health problems. Since Virginia has naturally acidic soil, this experiment would determine how the pH of soil affects the pH of water. This project was designed to help answer the question: do the pH levels of soil enough to affect the quality of water? This experiment used two trials. In each trial, eight soil samples were taken and filtered through runoff cups for 24 hours. Then the pH levels of the filtered samples were measured. As a result, the pH of the filtered samples increased from a pH of 5 up to a pH of 12. The pH levels of the different soils were high enough to affect the quality of water, and both lower and higher the pH to acidic and alkaline levels. These results do not support the hypothesis due to the major difference in pH levels between the results of the water filtered through the different soil samples. In addition, this project determined that soils from dry areas or near streets and sidewalks tend to be more on the alkaline side, while soils from wetter areas and with more vegetation tend to be more on the acidic side.

Jenilia Martin-The Effect of Water Purification Methods on the pH Level of Creek Water
George H. Moody Middle School

Soil may have an impact on the quality of water for human consumption. Small levels of soil help clean and kill harmful bacteria, making water safe to drink. However, high levels of soil in water can cause poor drinking water quality, loss of water supply, high cleanup costs, and/or potential health problems. Since Virginia has naturally acidic soil, this experiment would determine how the pH of soil affects the pH of water. This project was designed to help answer the question: do the pH levels of soil enough to affect the quality of water? This experiment used two trials. In each trial, eight soil samples were taken and filtered through runoff cups for 24 hours. Then the pH levels of the filtered samples were measured. As a result, the pH of the filtered samples increased from a pH of 5 up to a pH of 12. The pH levels of the different soils were high enough to affect the quality of water, and both lower and higher the pH to acidic and alkaline levels. These results do not support the hypothesis due to the major difference in pH levels between the results of the water filtered through the different soil samples. In addition, this project determined that soils from dry areas or near streets and sidewalks tend to be more on the alkaline side, while soils from wetter areas and with more vegetation tend to be more on the acidic side.

Thomas Gupton & Shane Turianski-Testing the Water Quality of Lewis G. Larus Park's Crocksucker Creek Sabot at Stony Point

This project was designed to test the water qualities of a creek located in Richmond, VA. The experiment evaluated ammonia, Ph, nitrate, nitrite, turbidity, and dissolved oxygen. Then the testers compared the data to the EPA's (Environmental Protection Agency) Virginia's healthy creek and stream conditions. The EPA monitors stream health and determines if a stream is healthy or impaired for the U.S.A. The original hypothesis compared the overall health of the stream to the drinking water qualities that were established by the Environment Protection Agency. The tests consisted of going out to Crocksucker Creek and collecting two jars of sample water. The sample waters were brought back to the lab and tested for ammonia, Ph, nitrate, and nitrite with the freshwater testing kit. Then used Vernier Graphical Analysis for turbidity, and dissolved oxygen. Then the data were recorded in the data collection sheet google sheets. It was hypothesized that the creek would be overall, based on the EPA guidelines, listed as impaired. This hypothesis was indicated by the fact that there were few observable living organisms when the stream had been visited prior to conducting the experiment. The results of the project concluded that Crocksucker Creek is not sufficient for drinking out according to the EPA's sufficient drinking water levels. And according to the results of the project the creek is polluting the James River with its water.

Charlie Lawson-The Effect of Different Growing Conditions on the Growth of Rainbow Chard
Dorothy Hamm Middle School

The objective of this experiment was to determine if *Beta Vulgaris Subsp* (also known as Rainbow Chard), grows better in soil, a hydroponics tower, or wick hydroponics. Hydroponics is when plants are grown without soil. *Beta vulgaris Subsp* is commonly known as Rainbow Chard. In this experiment the plants were measured every week in millimeters. Plants grown in soil were used as a control for the experiment. The hydroponics tower housed eight plants, the soil pots had eight plants (one seed in each pot) and the wick hydroponics system had nine *Beta vulgaris Subsp* plants. During the project, the soil subjects were watered every day, the hydroponics tower was activated every other day, and the wick hydroponics was constantly giving the plants water. The data was collected by recording the height of the *Beta vulgaris Subsp* in millimeters every week. The results of this experiment showed that Wick hydroponics grew the tallest and *Beta vulgaris Subsp* plants. It was hypothesized, and supported, that one of the hydroponic growing methods would be more successful than the traditional soil methods, as it was easier to control the exact amount of nutrients that were received by the plants.

Ecology & Earth Sciences B (MS EE-B)

First Place

Sophia Shoffner-Phosphorus Filtration in Simulated Streamwater Runoff
Swanson Middle School

The purpose of this experiment is to compare water filters, and their effectiveness in phosphorus extraction. The importance of this experiment is to combat the negative effects of algae blooms and this data could be implemented to improve Arlington's estuaries, which impact the Chesapeake Bay watershed area. This experiment tested the effect of the type of filter on the phosphorus levels in simulated fertilizer runoff. The hypothesis was that if the type of filter was changed then the phosphorus levels would decrease the most with natural filter two. First, phosphate water was used to simulate fertilizer runoff. Natural filters one and two were made by layering natural materials. For human made filter one, layers of metal mesh and cloth were used. For human made filter two, charcoal powder, sediments and cloth were stratified. Lastly, phosphate water was poured through each filter, testing before and after. According to the bar graph, natural filter two had the highest average change in phosphorus at 86 ppm. The dot plot showed that natural filter two had the tightest data cluster at a range of 25 ppm. Natural filter two was highly effective compared to the other filters. In summary, the hypothesis was supported. One outlier was that the experiment was designed to use stream water, but the phosphorus was too diluted, so a ratio of 200 mL tap water: 177 phosphate granules was used. Also, the water did not percolate through human made filter two. Further research can be done on different phosphorus tests' effectiveness.

Second Place

Olivia Zhang-The Effect of Ocean Acidification on Shell Weight Loss
George H. Moody Middle School

Due to the increase of human activities, ocean acidity has been rising. It has become a global issue and poses an immense threat to marine organisms and ecosystems. This process occurs as the ocean absorbs carbon dioxide from the atmosphere, causing a decrease in the pH of seawater. The all-time

low pH has a cascading effect on the chemical balance of the ocean, which results in far-reaching consequences for marine life. One particular effect of ocean acidification is the deformation of shells in calcifying species. Shells are made up of calcium carbonate, a mineral that is essential for the survival and reproduction of many marine species. The imbalance of carbonate ions can cause the shells to become smaller, thinner, or dissolve entirely. It can lead to reduced growth, decreased reproductive success, and even the extinction of species. The purpose of this project was to determine how ocean acidification affects the weight loss of calcium carbonate shells. Ten oyster shells were soaked in a solution for each pH interval for three days. The initial and final masses were compared. The results indicated that although the mean weight loss was minimal from five (0.7%) to eight, (0.2%) there was an exponential drop between four (6.9%) and five (0.7%). The data supported the hypothesis that if an oyster shell is soaked in water with a pH level of four, the weight of the shell will decrease the most. Based on the percentages determined in this experiment, there appears to be a direct correlation between ocean acidification and shell weight loss.

Third Place

Maya Umerov-Todoroki-The Effect of Nitrogen or Phosphate on Dissolved Oxygen Levels
Sabot at Stony Point

This experiment demonstrates the critical environmental issue called eutrophication. Eutrophication is a process where excessive richness of nutrients in a body of water, particularly nitrogen and phosphate, causes a dense growth of plant life and death of animal life from lack of oxygen. This frequently happens due to runoff from land as a result of intensive farming methods and poor sewage and waste management. Nitrogen and phosphates are nutrients which are essential for plant and animal growth. However, the overabundance of these nutrients in water can cause several adverse health and ecological effects, causing the body of water to become a dead zone with no life to be sustained. The question that is being answered through the experiment is how the level of nitrogen or phosphate affects the level of dissolved oxygen. The hypothesis of this experiment is that the more nitrogen and phosphate the water contains, the lower the dissolved oxygen levels are. The excessive nitrogen and phosphate feed into algae blooms. Then the algae will use up the dissolved oxygen of the water, creating a deadly environment for the organisms. To conduct this experiment, fertilizer and detergent that contain nitrogen and phosphate were used. The fertilizer contained both nitrogen and phosphate while the detergent contained only phosphate. Different amounts of fertilizer or detergent were placed into seven jars to test

the dissolved oxygen level over three trials. Following four weeks of trials, it was found that the more phosphate and nitrogen the water contained, the lower the dissolved oxygen level was. The jar with the most amount of fertilizer which contained both nitrogen and phosphate decreased the dissolved oxygen levels the most. This contrasts with the control jar which contained no fertilizer or detergent, making it suitable for abundant fish populations. The result can be explained by the fact that the larger amount of phosphate or nitrogen feeds into more algae blooms which steal more oxygen, creating a harmful environment for the organisms.

Honorable Mention

Dwani Suresh-The Effect of different Nutrient sources while using Hydroponic Systems on Different Plants

George H. Moody Middle School

Agriculture and farming have been around and stuck with us for thousands of years but soon with global warming and climate change our old ways will not be enough and we will have to adapt. Scientists have come up with the idea of Hydroponics which has slowly been proven to be very useful and in 20 years all of our food supply will be planted and grown through this system. This experiment was conducted to determine which nutrient/plant food if used when conducting the system of hydroponics would benefit plant growth the most. The experimenter hypothesized that "If the 36 tyrofnt source is compost when planted with hydroponics then the growth of the plant will be more sufficient". The control of this experiment is no nutrient source mixed into the water. Once all safety procedures were followed, the experimenter started to build the hydroponic structure. Using cardboard, egg cartons, a miniature DC water motor pump, and hot glue. Then attached plants and added water. Then measure the plant growth using inches. The hypothesis was proven correct as compost was the most effective and the least expensive. This experiment supports the different methods to agriculture and how our world has started to evolve throughout the years, for the better being of the earth. It shows what nutrient is most effective and needy, which is compost.

Alexander Perrelli & Derek Buchwald-The Effect of the Type of Soil on the Amount of Water Retained
Williamsburg Middle School

The rationale of the experiment was to determine how different types of soil affect water retention. This experiment showed that different soil types lead to different amounts of water being retained. This is important because trapping water in the soil reduces flooding and allows plants to grow. Research shows soil types with small rough particles retain more water due to the particles' increased ability to trap water. Finding out if a type of soil has these qualities is important to making agricultural decisions. For example, finding which soil type can retain the most water can help city planners decide what soil to use in areas that are prone to flooding. This is important in places with large amounts of impermeable substances, such as concrete, steel, and shingles. This experiment can also help find better ways to stop floods altogether. This experiment was conducted by pouring water into soil placed in a strainer positioned above a basin. The water sat on the soil for one minute to allow it to soak in or seep through. After that the water that drained into the basin was poured into a graduated cylinder to be measured. Between each test the strainers were washed and dried. In the experiment the soil types used were dirt, gravel, sand, and clay, dirt being our base. The hypothesis was that if the type of soil was clay, then it would retain more water due to its fine particles. The hypothesis was not supported. The soil that retained the most water was sand which has small and coarse particles. The one that retained the second most was gravel mostly due to the fact that the water was sitting on top of the rocks. Clay held the third most amount of water. Finally, dirt held the least amount of water. The data is useful because it depicts how the different types of particles affect water retention.

Zoe Schroeder-The Effect of the Type of Method on the Amount of Oil Cleaned Up Kenmore Middle School

Marine life is essential to the environment and counteracting effects of global warming because of a process performed by marine animals called a "biological pump". Oil spills are preventing this process and creating a negative impact on the environment. This project looks at what method of collecting oil from oil spills is most effective. The methods (kitty litter, dish soap, sponges, and rag) were tested by setting each method in a pan with water and oil to absorb the oil for 15 minutes. The data was collected by measuring the mass of the method and pan before and after each trial (dependent variable). The hypothesis for this experiment is if kitty litter is used then there will be less oil left in the water because kitty litter is an oil absorbent. Based on quantitative and qualitative data this hypothesis was not supported. Although the hypothesis was not supported, the qualitative data shows that the kitty litter was a close second to being the most effective method. The sponge method had an average mass of

326.4 grams but when the sponges were rung out the liquid collected was mostly water. To compare, the kitty litter method had an average mass of 137.8 grams but had more water than oil left in the pan. In conclusion, the dish soap method was found to be a solvent for oil and most effective. This is because it left less oil in the pan while having a greater mass than kitty litter.

Liu Shanshan-The Effect of the pH of Water on the Growth of *Salvia hispanica* seeds
George H. Moody Middle School

The pH of water is crucial to the health of many plants, such as *Salvia hispanica* seeds. The correct water pH is essential, as it can determine the number of nutrients the plant receives. To test the effectiveness of the pH of water on *Salvia hispanica* seeds, one can take many simple steps to find out what pH of water is best for the conditions of these seeds. After many trials, it can be concluded that a neutral pH is the best fit for *Salvia hispanica* seeds, as it supplies the plant with all of its necessities. From this inquiry, one is able to realize the importance of the pH of water on the growth of an organism and the statement, "if the pH of water is purer, or neutral, then the growth of *Salvia hispanica* seeds will be more evident" is shown to be true.

Nathan Yellin-The Effect of Nitrogen or Phosphate on Dissolved Oxygen levels
Sabot at Stony Point

Urban Heat Islands (UHIs) are a phenomenon where the urban areas are warmer than the surrounding areas due to building materials such as asphalt, concrete, and tar paper. The goal of this experiment was to investigate alternative materials that would attempt to remedy the UHI effect. It was hypothesized that a green roofing material would have the lowest heat absorption and heat retention rate. In this experiment a ten-gallon glass aquarium was lined with either no material, plain tar paper, tar paper painted white to mimic a 'white roof,' and sod to simulate a 'green roof.' Then a heat lamp with a GE clear heat lamp 125-watt(w) bulb was placed 25.4 centimeters away from the surface and then set to be on for 3 hours. Then a Vernier Temperature Probe connected to a computer running Vernier Graphical Analysis software collected temperature (°C) data every 30 seconds for 24,000 seconds. Based on the initial starting temperature the absorption rate was measured to when the temperature of the estimated heat lamp shut off point was reached. The retention rate was measured from the estimated

heat lamp shut off point to initial starting temperature. The results of this experiment demonstrated that the green roof had the lowest heat absorption and retention compared to the other materials that were tested. Thus, the original hypothesis was supported. This experiment indicates that green roofing has the potential to be a strong way to mitigate urban heat islands. This is important because it could help reduce climate change and energy bills.

Engineering & Technology (MS ET)

First Place

Sophia Rizvi - Bandwidth Battle: How Remote Work and Streaming Apps Affect Internet Speed
Grafton Middle School

Following the COVID-19 pandemic, the usage of video streaming services and videoconferencing applications has increased significantly due to remote work and online schooling. Bandwidth competition has become a major issue, resulting in low-quality video and blurred images. This experiment aimed to investigate which application consumes the most network bandwidth among popular video streaming services and videoconferencing applications such as Netflix, YouTube, Amazon Prime Video, Microsoft Teams, Skype, and Zoom. A novel tool was developed to determine and record bandwidth consumption across a person's home network. Multiple t-tests were performed, and the data showed a statistically significant difference in bandwidth consumption among the various apps, with Netflix being the most network bandwidth consuming app. The research provides new insights into the impact of work-from-home and at-home entertainment apps on bandwidth consumption, power consumption, and global carbon footprint. The findings are particularly relevant in the post-pandemic era, given the widespread use of such apps worldwide.

Second Place

Luka Tkabladze -The Effect of the Amount of Borax on the Electrical Conductivity of the Magnetic Slime Robot
Dorothy Hamm Middle School

This experiment was inspired by one of the newest inventions — the magnetic slime robot. This unique robot was introduced in 2022, offering a game-changing tool with promising applications in many fields, including electronics and engineering. For example, the magnetic slime is a conductor of electricity and can act as a circuit switch and repair agent. Controlled by neodymium magnets, the slime can be manipulated so that it can act like a “robot” and can be used to fix broken circuits. The purpose of this experiment was to simulate the newest slime robot and test whether the slime would be a better conductor of electricity when more borax would be added in the recipe. The hypothesis was that if more borax powder was added in the magnetic slime

used to fix a broken circuit, then the electrical conductivity of the slime would increase, as measured by the voltage and the brightness of the light bulb, because borax would act as an electrolyte and be an ionic conductor when dissolved in the water used in the slime recipe. To test the hypothesis, four slimes were made using different amounts of borax powder in the slime recipes. The experiment used an electric circuit board. After successfully creating a homemade version of the magnetic slime robot, the experiments were conducted on the four slimes containing different amounts of borax powder. In each of the three trials conducted for the four slimes, the brightness and the voltage of the light bulb were measured, and the data was recorded and analyzed. The experiment results did not support the hypothesis. The results showed that an additional amount of borax did not make the slime significantly more or less conductive. However, while the change in the amount of borax did not show any consistent trend in the change of the brightness of the bulb, the voltage of the bulb slightly decreased when the amount of borax was increased.

Third Place

Gabriel Cohen -The Effect of Communication Protocol on Network Communication Speed
Dorothy Hamm Middle School

TCP and UDP are two of the main communication protocols used on the internet. TCP is a more reliable, structured protocol often used where it is crucial that data is delivered in full and where each piece must be received. UDP is quite the opposite, having almost no reliability measures (not even the guarantee that packets will arrive in the right order), and simply a focus on delivering the data in its most raw form. Both protocols have their own purposes. The experiment aimed to answer this question: Is a certain protocol inherently faster, and by how much? To conduct this experiment, custom software was created in the Java programming language, found at [this link](#). This program would transmit/receive 10,000 packets of 1000 bytes each through TCP and UDP, across 5 different trials. This program was run over 2 computers connected to a local network and had the client automatically record times. The trials ran consecutively and very quickly. The results of the experiment showed that transmission by TCP was significantly slower than transmission by UDP. Additionally, trials in TCP varied significantly more than in UDP, which may be attributed to TCP accounting for lost or damaged packets. In conclusion, UDP is much quicker than TCP and has a much more consistent (and faster) speed than TCP over a local network.

Honorable Mention

Haya Malik-The Effect of Insulation Material on Heat Retention
Kenmore Middle School

This experiment analyzed the heat retention properties of three readily available and cost-effective materials. The experiment used styrofoam, wood, and rockwool to determine which material was the most effective in retaining heat. Air/no insulation was used as the control group. Boiling water was poured into a plastic box which was covered with a lid. The box with boiling water was fully enclosed by the insulation material and placed in a larger box. A thermometer was inserted through the lid of the box to measure the temperature in one-minute intervals for sixty minutes for all three materials. The final temperature at the end of one hour as well as the average temperature drop per minute showed that rockwool had the least temperature drop. This could potentially be because rockwool has high thermal efficiency and very high thermal resistance. Moreover, rockwool has an average melting point of precisely 1000 Celsius. Styrofoam was the second most effective insulator in terms of average temperature drop per minute. The analysis shows that the type of insulation does indeed affect the amount of time heat can be retained. Rockwool however has the best overall results. Additional studies should use more malleable materials/products to ensure an entirely insulated box and limited air leakage. More trials with each insulation material should also be conducted to guarantee accurate results and to collect a larger sample set. The experiment could be expanded by using even more materials with high thermal efficiency to see which materials perform the best. A cost versus thermal efficiency comparison can show which materials provide the highest return on investment.

Honorable Mention

Sophie Parikh-The Effect of the Number of Fins on Distance Traveled
Williamsburg Middle School

The aim of this experiment was to establish if different numbers of fins affected the distance that a paper rocket traveled. Fuel efficiency is important to the aerospace industry. Being more fuel efficient will allow aircraft and spacecraft to use less fuel and still go far distances. Learning about aerodynamics can help find better ways to be fuel efficient. This experiment can help find ways to be more fuel efficient by learning about the relationship between the number of fins and the distance flown. This experiment can also help find the number of fins that would help allow for the optimal aerodynamics. In this experiment, an experimenter launched paper rockets and measured the distance from the launching point to the location where the rocket

first made contact with the ground. There were 7 different levels of IV: rockets with 0 fins; rockets with 1 fin; rockets with 2 fins; rockets with 3 fins; rockets with 4 fins; rockets with 5 fins; and rockets with 6 fins. The hypothesis was that 4 fins would help the rocket travel the farthest distance, and it was supported with 4 fins, on average helping the rocket fly the farthest. 6 fins flew the second farthest distance, 3 fins flew the third farthest, 2 fins flew the fourth farthest, 5 fins flew the fifth farthest, 0 fins flew the sixth farthest, and 1 fin traveled the least distance. 0 and 1 fins averaged significantly less distance flown, while 2 fins, 3 fins, 4 fins, 5 fins, and 6 fins had much more similar, and longer distances flown.

Angelo Fox-Shin -The Effects of Length on the Buoyancy of a Dowel
Dorothy Hamm Middle School

Buoyancy can drastically change depending on an object's shape despite its mass and density being the same. This experiment was conducted to see if the length of a dowel affects its buoyancy in water. The hypothesis is that longer dowels will be more buoyant because the surface area of the dowel is more dispersed. Three trials were conducted comparing the buoyancy of three different lengths of dowel in gelatin. Buoyancy is the upwards force exerted from water as the object lowers in the water. Areas lower in the water have much more pressure. Lengths of 2.54, 5.08, and 7.62 cm dowel were cut for the three trials. The dowels were placed in a 15.24 x 22.86 dishpan containing two packets of colored gelatin. Once the gelatin set and dyed the wood, the angle would be measured and recorded for each dowel. The difference in the tilt angle between the shortest and longest dowel was 16.64 degrees. The results supported the hypothesis, with all three trials, the longest dowel being the most buoyant out of the three.

Nora Lyon-The Effect of the Length of a Trebuchet's Short Arm on the Distance the Payload is Launched
Swanson Middle School

This project was completed for the purpose of designing a more efficient way of launching small objects for various uses, and to gain more knowledge of engineering. The problem statement was the effect of the length of a short arm of a trebuchet on the distance it launches the ammunition. First a trebuchet model was designed, then built with the help of the technology education teacher. After the trebuchet was built, it was brought to an open area, where each arm length was tested 10 times and the results were documented. The results were inconclusive because while the trebuchet was initially being tested, only attempts that went two metres or

more were documented. However, by the time the final arm, the 0.39m, was tested, all the attempts were documented due to time constraints. Because of this, the averages for each Independent Variable level may not accurately reflect the actual data. The only data inconsistency was one particular attempt with the 0.73 metre arm. The ammunition was launched almost 11 metres, or almost 36 feet. It is still unknown what caused this. The video of this attempt was reviewed several times, and there were no anomalies that could have caused this. The objectives were met, since a machine was created that can launch small objects, and there was a lot of technical knowledge gained along the way. This experiment can be applied for the construction of other lever-based machines, and any other machine that can launch projectiles.

Anika Parashar-Plant Disease Detection Using Deep Learning
Hidden Valley Middle School

Convolutional Neural Networks (CNNs) are a type of neural network that specialize in image classification, object identification, and recognition. The objective of this research project was to contrast between the accuracies of two CNNs. The hypothesis was, if the CNN model is GoogLeNet, then the accuracy will be the highest. The independent variable was the CNN model (AlexNet and GoogLeNet), the dependent variable was the accuracy in percentage, and the control was the comparison of both the models. Two algorithms, each one mimicking the structure of AlexNet and GoogLeNet, were written to conduct this experiment. First, all the needed libraries were imported into each algorithm, the code was written in Jupyter Notebook from Anaconda Navigator. Some layers were frozen, and the image sizes were determined after the dataset was loaded. The algorithm was given the training data so it could recognize any patterns or important features, this is called feature extraction. The algorithm was set to give loss and accuracy plots, for the validation and training sets. The validation accuracy is a better way to measure CNN accuracy because the training set is constantly shown to the algorithm, whereas the validation set is only shown a couple of times. This was repeated with five datasets. At epoch 0, training and validation accuracies were low, but as the hours passed and it reached later epochs, both accuracies improved. AlexNet had a greater training accuracy however, GoogLeNet had a greater validation accuracy, therefore, GoogLeNet is the more accurate CNN model.

Eesha Pellreddy-The Effect of Different Soundproof Materials on their Ability to Restrict Sound
George H. Moody Middle School

Soundproof materials are used to prevent sound. The purpose of this experiment was to ascertain which soundproof material was most successful. The hypothesis was if each soundproof material is tested on which helps annihilate sound the most, the acoustic foam board will have the most effective result. The experimenter conducted a series of experiments to get accurate results. Even though the acoustic foam board had an acoustic texture, the thickness of the material also played an important role in this experiment. The results of this experiment did not support the hypothesis. In the hypothesis, it was predicted that the acoustic foam board would have the most effective result. In conclusion, according to the experiment that was conducted, the thickest material will have a better outcome. The experiment revealed that the soundproof curtains were most effective.

Isaac Phillips-Determining the Amount of Weight a Handmade of Cardboard, Other Scrap Materials, and a Pulley System will be able to Pick-Up.
Sabot at Stony Point

The purpose of this experiment was to see if simple machines could be used to make a working model of a human hand. It was decided to use a pulley system to simulate the muscles in a real human hand to let the cardboard hand open and close. Two different hands were made to carry out this experiment, and the crafted hands were compared to a real human hand. Both the crafted hands and the human hand were tasked to pick up different objects that range from a pencil to a small cup of water. The objects were chosen to simulate real things that hands might have to interact with during a normal day. The main difference between the two hands were that one of the hands had the pulley system operate on the outside of the hand, while the other hand had the pulley system operate on the inside of the hand. The results of this experiment indicated that a model of a hand could be made using cardboard, tape, scissors, and string that was capable of picking up different objects. However, the hands that were made out of cardboard were not as effective as a human hand. This supported the hypothesis that a hand could be created using artificial materials that could imitate a human hand, but it also supported that a human hand would ultimately be more effective.

Emily Ramsey-The Effect of Different Bus Routes on Efficiency
Williamsburg Middle School

The main purpose and objective of this experiment is to make sure that all students that ride the bus aren't

late to school for something that they cannot control and to make sure they don't have to cross any dangerous streets while getting to and from their house to their bus stop, especially when timing of school is closer to rush hours. The approach of this experiment was to start a stopwatch about five seconds before the driver has started, every time a trial has started the driver and observer would make sure to start in the bus loop and come back to there after driving. The observer will then drive to each stop for the bus route. At each stop make sure to wait two minutes and then drive back to the bus loop so it's similar to how the actual bus routes work. Then take the first three bus routes and average them together for the first trial. For the second trial the observer should take the fourth, fifth, and sixth bus routes then average them out. Finally for the third trial take the seventh and eighth bus route, add them together and divide it by two. The key results were that the range from the APS Bus Route was four minutes while the Designed Bus Route had 1.36 minutes rounding to one minute and that the highest number for the APS Bus Route was twenty-eight minutes and the Designed Bus Route twenty-two minutes but it was averaged between three bus routes.

Aryaman Rane-Voltage Produced by a Bicycle Driven Across a Short Distance Connected to the Shaft of a Generator

George H. Moody Middle School

A lot of energy or electricity is wasted in everyday activities such as driving cars, riding a bike, etc. The experimenter was hoping to use a generator in a hypothetical situation where they were to attach a generator's shaft to a bicycle wheel to produce electricity while being used to charge small, household appliances and items. The results were a bit underwhelming but not bad in any regard because the experimenter was using a very short distance of measurement; around 10 meters. The experimenter discovered that the amount of voltage produced by the generator on a 10-meter test run is around 0.15 volts.

Adrito Sarkar-The Effect of Sound Reduction Articles on Volume(dB) of VJAS

George H. Moody Middle School

The purpose of the independent research project was to determine which soundproofing material was the most effective. The experimenter also tested if the results would change between Treble and Bass music. The experimenter believed if the experimenter used shaped foam, the decibel value would be the lowest. The experimenter also believed that changing the music from treble to bass would not change how much the

soundproofing material absorbed the sound. Each soundproofing material was tested by putting a speaker in a box, lining the inside of that box with the respective material, and measuring the outside decibel value. Shaped foam ended up with the lowest decibel value, so it was the most effective in reducing the noise. This is likely due to the shaped foam being created in such a way that if the sound waves do not get absorbed by the foam, they will just lose energy due to the laws of physics. So, in the end, the experimenter's hypothesis was accurate.

Human Behavior (MS HB)

First Place

Blake Thorsen-The Effect on Different Types of Music on the Percentage of Words Memorized
Williamsburg Middle School

The rationale of this experiment was to determine if different types of music have an affect on a person's memory. Studies have shown that music can help improve memory by reactivating different parts of the brain that are associated with memory. Other studies have shown that listening to classical music can reactivate these parts of the brain as well. Music has also been shown to cause emotions, which can help lay down new memories. This topic is important because people have to memorize many things throughout their daily lives. While the experiment was being conducted, students in 8th grade were shown a series of twenty words for each type of music and were given twenty seconds to try to memorize each of the words while listening to the music. The levels of independent variables (IV) in the experiment for each different type of music were classical, rock, pop and country. The control in the experiment was no music. Students were then given a minute to try to write down as many words as they could possibly remember. After all of the students were tested, all of the scores for each level of IV were averaged out to find the mean for each of the three trials. The hypothesis was that if classical music was being tested on the groups of students, then the percentage of words would increase because classical music can help reactivate different parts of the brain, making it easier to retain new information. The hypothesis was supported. Out of all of the trials, classical music had the highest percentage of words memorized, having a mean of 28%. The lowest percentage of words memorized occurred when no music was played for the students, which resulted in a mean of 19.4%.

Second Place

Sajeela Ahmad-The Effect of Suggestion on Visual Memory in Youth and Adults
Benton Middle School

The objective of this research was to see if participants tested in this experiment, separated between under eighteen and over eighteen, had any change in their visual memory of a slide of faces after being suggested something false, or if they include the false fact in their memory. The hypothesis was: "If a person is suggested a false fact, then they will treat it as a true fact instead of their own memory because they trust the person

suggesting being better informed.” The independent variable was being suggested a false fact, and the dependent variables were how many faces were described correctly (on both day 1 and day 2), and whether they included a description of the face that was suggested to be on the slide but was not on the slide on day 1. The planned procedure was to ask parents if they or their children could take part in this experiment. If the parent agreed and signed the shared consent form, they would share a time that was suitable to meet for two consecutive days. This experiment was conducted over Zoom, so there were no risks of COVID-19. My data was separated between participants under eighteen and over eighteen, to see if there was a difference in their memories or their susceptibility to suggestion. I had hypothesized that “If a person is suggested a false fact, then they will treat it as a true fact instead of their own memory because they trust the person suggesting Being better informed.” From this experiment, I found that being suggested does not significantly change the number of faces a participant describes correctly, and most people do not include the suggested face in their descriptions. Being suggested does not affect the participants memory over a gap of 1 day between tests.

Third Place

Jori Willford-What is the Effect of Marketing Transparency on Company Trustworthiness?

Thomas Jefferson Middle School

The purpose of this research was to learn how marketing transparency affects company trust. Better understanding how marketing transparency affects consumers and the trust they have in the companies they purchase products from can help companies market their products more effectively. 24 people were asked to view an ad and complete a survey. Half of the people saw an ad that was honest and showed more information about the product, including how it was made and where it came from. The other half saw an ad with little to no information about the product. This study found that people who had more information about the product rated the company as slightly more trustworthy but were not more likely to say they would purchase the product compared to the people who had no information about the product. All in all, there wasn't a drastic effect of marketing transparency on the company's trustworthiness.

Mathematics: Patterns & Relationships (MS MP)

First Place

Rishvanth Balasubramanian-The Effect of Unorthodox methods in Comparison to Standard Methods of Algebra and Higher on Significance of the Results Obtained by Applying it to the Collatz Conjecture
George H. Moody Middle School

The Collatz Conjecture was developed by German Mathematician Lothar Collatz and has steadily disassembled the attempts of many mathematicians that wanted to either prove or disprove it. Recently, many mathematicians have attempted this problem with various branches of mathematics and have still been unsuccessful. The main purpose of this mathematical experiment is to investigate the significance in comparison of unorthodox methods and standard methods. Along with that, this experiment also investigates the foundations of the Collatz Conjecture itself and also attempts at uncovering some important secrets. If the use of an unorthodox method is employed, then the results will be significant. To support this claim, 2 unorthodox methods and 1 standard method were created and chosen for this investigation. Both of the unorthodox methods revolve around some previous method created in the field of mathematics and build up from there. The standard method involves applying matrices and determinants to the problem itself. The outcome of the standard method produced a sequence that had no previous relevance in mathematics to which it could be connected with. On the other hand, both of the unorthodox methods exhibited some patterns. The unorthodox methods might not have created patterns that continue indefinitely, but the unorthodox methods still produce significant results, whereas the standard method produces no important results at all. It can be seen that unorthodox methods prove to have a greater influence in conjectures than standard methods itself, but the complete study of the type of problem must be done as this is variable.

Physical Science & Astronomy (MS PA)

First Place

Pranav Sundarrajan -The Effect of Varied Added Naturally Occurring Substrates on the Efficiency of Voltage Production in a Microbial Fuel Cell (MFC):
George H. Moody Middle School

Over the past few decades, microbial fuel cells have become increasingly popular. Despite rarely being displayed on commercials, MFCs have experienced significant technological advancements during this time. A microbial fuel cell is a device that utilizes electroactive bacterial cultures from microbe sources to generate electrical power. Various factors such as salt concentrations, the composition of salt bridges, and the microbe source incorporated jointly affect the performance of a microbial fuel cell. This particular research paper, however, focused on how different naturally added substrates affected the amount of voltage produced in a microbial fuel cell. Fifty grams of acetate, boric acid, glucose, and cellulose were added to four sets of microbial fuel cells and the voltage was measured for ten trials. Additionally, a control group was utilized for a standard comparison. T-tests comparing the results of each independent variable to the control group indicated an insignificant difference between the means of the groups ($t = 0.176 < 1.734$, $t = 0.614 < 1.734$, $t = 0.453 < 1.734$, $t = 0.243 < 1.734$ at $\alpha=0.05$ and $df \approx 18$). Additionally, the p-values highly exceeded 0.05. Therefore, the data did not support the research hypothesis that If cellulose was incorporated as a substrate, then the voltage of the microbial fuel cell would be the highest. Potential errors in the experiment included a weak salt bridge caused by uneven placement of salt (NaCl) and varying bacterial cultures present in the microbe sources. Improvements for this experiment include creating a salt bridge where salt is evenly distributed and waiting for a longer period of time before testing the voltage of each microbial fuel cell (time must be constant). To further validate the results, further studies must be conducted at a real-life scale consisting of logistical difficulties.

Second Place

Kyra Coronado-Wager-The Effect of Water Depth on Wave Velocity
Dorothy Hamm Middle School

The purpose of this experiment was to find the relationship between water depth and wave velocity. A wooden block was dropped into different measurements of water. The time the block hit the water and caused the

wave to the time the wave hit the other side of the tank was recorded. It was hypothesized that the deeper the water the faster the wave, because the deeper water would have less friction than the shallower waves. The place the block was dropped, the location of the tank, and the source of water remained the same. With the results of the experiment, the hypothesis was supported by the data because the fastest times came from the deepest measurements of waters. The experiment could be improved by having a way to more precisely measure the time.

Third Place

Avery Hanger-How Does the Amount of Water Affect the “Flip” of a Bottle?

Sabot at Stony Point

This study’s purpose was to show how the amount of water and the size of bottle affects the ability of the bottle to land in an upright position after it is flipped by a person. Flipping a bottle is the ability to toss a bottle into the air, have it rotated 180 degrees, and then land in an upright position. When starting this experiment, the goal was to test how much water can make a bottle hard to land right side up, as well as developing an understanding of the science behind a bottle flip and the concept of center of mass. When testing this theory, multiple people participated as “bottle flippers.” They were asked to flip multiple bottles with their right hand 10 times. The bottles were filled with different amounts of water. In conclusion, the bigger 828 mL bottle with 355 mL of water flipped rightside up more often than the other bottles tested. It was originally hypothesized that a smaller bottle will be harder to flip because the center of the mass is smaller. It was also hypothesized that a bigger bottle with the same amount of water would be easier to flip because the center of the mass is bigger. The data indicated that the original hypothesis was supported.

Honorable Mention

Keira Brickley & Weston Montpetit-What Materials Result in the Lowest Percent Error in a Calorimeter

Sabot at Stony Point

The purpose of this experiment was to make the best insulated calorimeter with a low percent error. A calorimeter is used to measure the calories in a food item. Knowing calories in food is important because the number of calories that people consume can affect a person’s health and weight. In order to conduct this investigation, we used different insulating materials to reduce heat loss. This helps make caloric

measurements more precise. The materials that were tested were cardboard, plastic, Styrofoam, and aluminum foil. For each of the materials tested, one Sun chip was burned while the change in the temperature of water in an aluminum can was measured. Aluminum was used because it is known to be a good conductor of heat energy. The results of the experiment indicate that plastic and cardboard were the best insulators and aluminum was the worst. The results also showed that the use of any material was more effective in capturing heat energy than when no material was used. In order to determine the efficacy of the different materials, the percent error was calculated between the known calories on the nutrition label and the calculated number of calories. The results of this experiment can provide insight into the accuracy of food labels, helping people to understand how many calories they are consuming, and help to reduce health risks caused by malnutrition and obesity.

Honorable Mention

Shruthi Subramanian-Research of Effect of Various Types of Metal on Melting Ice
George H. Moody Middle School

The purpose of this lab is to see which metal will melt ice the fastest. The experimenter is doing this because many people have slipped and fallen down from the ice on the handrails beside the stairs outside. After an icy night. So, they conducted this experiment to help change the metal that they use to prevent injuries from happening. To conduct this experiment, you would need different types of metals and ice. You would place a piece of metal on top of the piece of ice. You would want to make sure that the size of the ice is similar to the size of the metal. Then you would wait and see how long it takes the ice to melt completely. Once you do that you can move on to your data and the conclusions. The data the experimenter was to find out which metal melted the ice the fastest in this case that was the copper. They had constant ice melting at room temperature and with no metal or anything else on the container. Then they had various types of metals like brass aluminum and copper. The copper melted the ice in the fastest amount of time than the other. The aluminum and copper were very close for the amount of time it took to melt the ice. The ice melting on its own definitely took the longest amount of time. But the brass didn't do the worst either. The data showed that the brass took half the amount of time that it would've taken the ice its own to melt. After you have all of the data you can come to conclusions. In this case, it showed that copper was a better conductor than the other metals. This is because copper is a metal which shows that it is also a conductor. Although all of the metals are conductors copper conducted heat in the fastest amount of speed compared to the other types of metals. The heat from the metal will be transferred to the ice. This causes the ice to turn back into the water because of the heat.

Plant Science & Microbiology A (MS PM-A)

First Place

Devansh Kumar -The Effect of Different Irrigation on Tomato (*Solanum lycopersicum*) Growth
George H. Moody Middle School

About 10,000 years ago from now, humans began to plant and harvest crops, transitioning from the original hunter-gatherer lifestyle to establishing communities. Since then, ways of irrigating crops and plants have altered many times, and in many different ways. Irrigation has evolved from carrying buckets of water from a river to entire systems of pipes that run underground and dispense water from underneath the soil to the plants. The purpose of this experiment was to find out what irrigation method (drip, flood, rain, or underground) will cause a *Solanum lycopersicum* plant to grow the most. Each irrigation method was tested on 10 plants each, starting from when the seed was placed and buried in the soil, to 14 days after the planting. The results indicated that flood irrigation caused the greatest average amount of plant growth in the *Solanum lycopersicum* plants. This method had an average of 6.75 centimeters, and a standard deviation of only 0.75461543 centimeters, indicating that the mean is accurate. The least effective irrigation method in this experiment was underground irrigation, with an average height of 4.6 centimeters by the end of experimentation. The data did not support the hypothesis that drip irrigation will cause the most plant growth, as drip irrigation came in as the second-best method, with an average of 6.45 centimeters of height at the end of the 14-day experimentation period.

Second Place

Madeline Mangi & Clara Amundson-The Effect of the Type of Plant on the Amount of Time Taken to Remove CO₂ from the Atmosphere
Williamsburg Middle School

This experiment: the Effect of the Type of Plant on the Time Taken to Remove CO₂, could be crucial in current day-to-day lives because Carbon Dioxide (CO₂) emissions are one of the largest current contributing factors of climate change. This experiment could help to decrease the average ppm (points per million) of CO₂ in the atmosphere. The purpose of this experiment is to find a simple and efficient way to control the amount of CO₂ being released into the atmosphere. It was hypothesized that if 5,000 ppm of CO₂ was pumped into an airtight

terrarium with sprouting potatoes, it would be able to remove the CO₂ the quickest. This is because potato plants are starches which consist of long strands of glucose, and during photosynthesis plants convert CO₂ into glucose. Therefore, potato plants would be accustomed to take in CO₂ in the least amount of time. The experiment process began with germinating the seeds for two weeks; the germination varying on the type of plant. The sprouts were then placed in a jar with a CO₂ tester. After the jar was sealed, CO₂ was pumped into the jar, and a stopwatch was set. When the tester read 414 ppm the timer was stopped, and the time was recorded. These steps were repeated three times per variable. The hypothesis was supported; the potato sprouts took an average of 17.37 minutes, basil sprouts took 29.02 minutes, mustard green sprouts took 27.38 minutes, and the control took 41.07 minutes. Overall, this experiment was conducted in the pursuit of finding an accessible plant that could absorb the most CO₂ in the least amount of time. This is important because climate change is caused by the release of greenhouse gasses into the atmosphere, with the leading gas being CO₂.

Third Place

Mason Mahabir-The Effect of Fertilizers on Seedling Growth
Benton Middle School

The germination of the seeds depends on the nutrients stored within them. Once they germinate the seedlings starts to obtain nutrients and moisture from the soil using their newly developed root system. Plant species have different nutrient requirements for good growth. Flowering plants can be classified as plants with one embryonic seed leaf (monocots), or two embryonic seed leaves (dicots) called cotyledons. Numerous fertilizers have been developed and applied to meet the requirements and support the growth of mono- and dicot plants. This study evaluated the effect of four fertilizers: two powdered and two liquid, with different nitrogen, phosphorous and potassium (NPK) ratio on stem elongation and growth of bean (*Phaseolus vulgaris*; dicots) and corn (*Zea mays*; monocots) seedlings. The objective of this study was to distinguish the requirements for stem elongation and growth between the two flowering plant types. The tallest bean seedlings with an average of 38.7cm, grew in presence of a liquid fertilizer with 18-18-21 NPK ratio and multiple micronutrients. The corn seedlings were sensitive to the liquid fertilizers and did not develop in their presence. The tallest corn seedling (30cm) developed in presence of a powdered fertilizer with 12-0-0 NPK ratio. The data obtained in this study can be applicable in selecting appropriate fertilizers and minimizing the pollution and eutrophication of aquatic ecosystems caused by over fertilizing.

Honorable Mention

Olivia Martin-The Effects Mouthwash has on Bacteria on the Teeth
Benton Middle School

The purpose of my experiment was to see if the addition of mouthwash changed the number of bacteria on my teeth. Two different mouthwashes were used to show which worked the best to decrease the number of bacteria on my teeth. This experiment was conducted over a period of three weeks, each week consisting of four sample days. Every week started with a different variable. The variables included toothpaste only, toothpaste and mouthwash A, and toothpaste and mouthwash B. The end results did show that toothpaste and mouthwash B worked better at decreasing the number of bacteria than toothpaste and mouthwash A, and just toothpaste alone. Based on my results, I can conclude that adding mouthwash to a daily tooth brushing routine does indeed decrease the number of bacteria in the mouth.

Honorable Mention

Jordan Haught-Effect of Interstellar Rock on the Cellular Survival of *Lepidium sativum* (Common Garden Cress)
George H. Moody Middle School

In the more recent years, NASA has considered colonization of suitable or viable interstellar installments, such as Mars or Saturn's moon Titan, a present concern or option using their resources and research teams. The purpose of this experiment was to provide sufficient or somewhat usable information to assist a possible agricultural development for a stable food source by possible colonies on these settlements. The plants were tested by placing the seeds within separated planting sections of 83 tests per soil base. The plants were watered at the same time with the same amount of water daily and had a consistent light source using artificial lighting. The plants were all placed in the same area to prevent possible environmental circumstances from voiding the data, however this could have occurred due to unexpected temperature decreases. The volcanic ash plant group grew the most and deviated positively from the control group by 0.55 in section 1 and 0.6 in section 2. The dust-bases soil bases appeared to have the most success in growth, as they did not harden or restrict the water's ability to reach the seed for growth. The hypothesis, "If *Lepidium Sativum* is grown inset in an environment in which contains rock types found on other planets, then the environment will have a significant effect on Cress plants to cause a degeneration in the structural integrity of plant cells of the Garden Cress", was supported as the data showed beyond significant data deviation negatively and positively

(dependent on the soil base of inquiry). Based on the researcher's findings, there was an apparent connection between the effectiveness of soil on the growth of the plant's dependent on their composition and reactive properties with water.

Rishi Akula-The Effect of Different Levels of Water Acidification on the Germination of *Typha latifolia*
George H. Moody Middle School

The water on Earth is becoming worse and worse every day. With the quantity of pollutants released daily, it is practically impossible to repair the harm that has already been done. Analyzing the limits of acidity tolerance for cattail plants can help people manage their impact on the environment. This analysis can also be used to determine whether there are any other, more significant plants, such as cattails, that this might potentially have an impact on. It was hypothesized that the plants wouldn't survive if the water's acidity level was higher. This is so that cattails, which require a specific kind of water with a balanced pH, can live. Gathering the materials required for the experiment would be the first of the stages to be taken. Three seeds were inserted into each of the 40 pots after they had been equally stuffed with soil. To increase the water's acidity, lemon juice was added to two of the various freshwater samples. One sample was left alone, while the final one had baking soda added to it to lessen its acidity. The several pH values utilized to measure the various acidity levels were 2.0 pH, 5.0 pH, 7.0 pH (the constant), and 9.0 pH. For the repeated trials, 10 pots were utilized for each of the several pH values. The cattail plants were watered daily, and the soil was always moist. The temperature around the growing plant was always around 70 degrees Fahrenheit to mimic the average temperature of a freshwater biome. Clearly, this project was extremely necessary for the well-being of Earth.

Maya Aravindank-Research of The Effect of the type of medium on the height of the plant
George H. Moody Middle School

In 1937, William Frederick Gericke, a professor at the University of California, Berkeley, claimed plants could be grown in a mix of nutrients in water instead of soil. The public and Gericke's colleagues doubted this, but he was the first successful person to prove that plants could be grown in other mediums besides soil, by growing 25-foot-high tomato vines, using water and nutrients. He called this method "*Hydroponics*," and the results of the experiment spurred further research. Research was led by the University of California scientists,

exposing many benefits related to soilless plant cultivation (Espiritu, 2022). The intent of this experiment was to see how growing plants in other mediums could affect plant growth, by growing them in soil and compost. If the same level of nutrients were provided, then plants could grow in mediums, other than soil as well. Four plant pots of the same size were bought from a local store. A location was picked in the house that receives an adequate amount of sunlight. 16 tomato plant seeds, 3.4 pounds of compost and soil were bought for the experiment. The whole experiment was split across 4 trials. Each trial had 4 pots and in pots 1 and 4, half a cup of soil was added using a measuring cup. In pots two and three, half a cup of compost was added. One baby plant seed was placed in each pot. All the pots were placed next to each other in the location chosen. From day one to day twenty-five, one tablespoon of water was added to each plant. The plants were observed visually to see if they were growing. On every fifth day, the height of the plants was measured in inches and centimeters. Whenever the plants were touched, the hands were washed. The purpose of this experiment was to see if plants could grow in other mediums besides soil. At the end of the experiment, the data did not support the hypothesis that if the same level of nutrients were provided, then plants could grow in mediums, other than soil as well. The plants grew only in pots that had soil but not in compost. The compost chosen could be of poor quality or the plant species chosen grows well in poor soils (Trautmann, Richard, Krasny, 1996). Plants tend to grow better in soil because it provides support, nutrients, and water to the roots. Another study explains adding compost can take your gardening skills to the next level. Scientists claim compost improves tomato growth, fruit production, and disease suppression (Blackstone, 2018). Plants can grow without soil, but they would need support, the proper amount of water, air to their roots, and ample nutrients (Rhodes, 2014). A way to improve this experiment would be to have a blanched mix of compost and soil. The second way would be the amount of water. The amount of water could affect the plant's growth.

Roxana Cartin-The Effect of Different Age Levels on the Number of Bacteria Found
Williamsburg Middle School

The question being answered through this experiment is how will different age levels affect the number of bacteria found in different areas of schools? The project is important because it shows the significance of hygiene in human lives. People who make health and education policy will be interested, because the results may tell them why and how to introduce or reinforce hygiene education. An issue many people have faced in recent times is hygiene. With the COVID-19 pandemic, and the many variations of it, it is highly important to maintain hygiene within both adults and children. The objective of this experiment was to find the effect of the location of biological samples on the amount of germ culture. To conduct research, three school levels,

which included elementary school, middle school, and high school, had bacteria swabbed and placed into an incubator. In each school, three new variables were included, these were desks, door handles, and water fountains. The key results of this experiment concluded that elementary schoolers found to have the most bacteria in their school environment. It was hypothesized that the elementary school age group will collect the most bacteria, because they have not been taught hygienics as well as older age groups. The hypothesis was supported; however, one part of the experiment contradicted the main results. The water fountain trials had the most bacteria for the middle school age level, not elementary schoolers. A possible reason for this could be that middle schoolers have difficulties with oral hygiene due to having braces and teeth aligners.

Geunyoung Chung-The Effect of Different Amounts of Soap Water on *Phaseolus vulgaris* (Green Beans)
George H. Moody Middle School

Drought is a natural disaster that occurs when there is very little rain or a high shortage of water. It is very responsible for the high losses on the production of food crops, as well as harming the environment and dismantling the ecosystem of nature. However, as human development increases, this natural occurrence has been constantly increasing and becoming more common in society. Also, the increase of carbon dioxide emissions caused the land to become warmer and drier causing the plants to require more water than needed to survive. This is causing water to run out at a faster rate than its availability, leading to a risky downfall to fresh water available for humans. Through this experiment, the researcher intends to find a suitable substitute for water that does not negatively affect a plant's growth and has similar benefits as fresh water. Greywater. The researcher used a ruler to measure the final height (in centimeters) of the plants at the end of every week. The overall and average height of the plants and their different levels of variables were collected in the last week of the experiment (No soap: control, 1mL of soap, 2mL of soap, 3mL of soap). The hypothesis for this experiment was that if soap water is added to the green beans, there will not be a significant difference between the plants watered with regular water. After analyzing the data, the hypothesis was proven to be correct. The researcher discovered that there was no significant difference between the use of water and soap water on green beans (the plant tested). However, despite the multiple trials and controls that were used, this experiment would be more accurate if it was tested using different types of plants, and not just one. Furthermore, if this experiment was done at a greater scale, then there may be a change to the data, and offer more variety and diversity to the final results.

Darsh Daddala-The Effect of Eggshell Fertilizer on a Plant's Growth
George H. Moody Middle School

This experiment will test the effect of eggshell fertilizer on the growth of plants over the course of eight days. Locals will see the results of this experiment and make the decision to start using eggshell fertilizer when growing plants. This method is already used frequently, but the experimenter thinks that this fertilizer is better than any other unnatural fertilizer that may pollute the environment (Kalaivani Dayanidhi and Noorjahan Sheik Eusuff, 2021). There are also many economic advantages, such as some countries that are in poverty and use eggshells as fertilizer. Eggshells get thrown all the time, and people can conserve and reuse these shells (Daniel Azevedo). The purpose of this experiment is to test the effect of eggshell fertilizer on plant's growth. The experimenter's procedures go as follows. The experimenter first filled up soil to the pot of the plant up to 2 inches for every pot. The experimenter then poured the soaked garden cress seeds on top of the soil (Cress plants/grow plants, Date published N/A). The experimenter then started the process of pouring the eggshell fertilizer onto the soil according to the levels of IV. The results showed that the third level of IV had the tallest growth of the cress plants due to the amount of eggshell fertilizer applied to the soil.

Nitya Gandhi-Effect of the different pH levels on the plant growth.
George H. Moody Middle School

Over the last few weeks exploring acidity is what determined the native (original) soil pH condition present, and how agricultural practices have affected soil pH over time. This summarizes and discusses how producers can adjust soil pH to optimize crop production. Remember for the crops common to our area the optimal pH is approximately 6.3 to 7.3 and acid soils have pH readings lower than 7 while basic soils are above 7. While soils in our area may have pH readings in the 8 range, typically aren't like the alkali soils. If the soil pH is between 7.3 and 8.4 there is really no concern regarding plant growth and nutrient availability. These soils contain some free calcium carbonate (limestone) but low salts. While there may be some concern with the carryover of some herbicides, these soils are fine. While the pH could be lowered, the cost is prohibited on a farm field scale. The exception would be for homeowners wanting to plant acid-loving plants like azaleas and rhododendron. Here, for a small area, the application of elemental sulfur or products like aluminum or iron sulfate is appropriate and available in most home and garden departments. If the pH is higher than 8.4 but not alkaline, or high in salts, a major problem could be iron deficiency. In a landscape setting, it may be practical to apply foliar iron but on a farm field scale, it is better to select crops less sensitive

to iron deficiency, say wheat vs. soybean, or varieties/hybrids developed to be tolerant of this deficiency. If the soil has a high pH and is high in salt, there could be salt problems. These are termed alkaline soils and a major problem is a lack of soil structure. Here we tend to have small areas with high salt content and poor soil structure. The term used by producers is “slick spots.”

Radhika Goyal-The Effect of Different Materials on Apple Ripeness
George H. Moody Middle School

Over the years, research has been found which proves that an apple could have a better ripening factor if kept in a specific material. The ripeness of an apple is important because ripe fruit provides the nutrition needed in an average person’s daily diet such as Vitamin C, Vitamin A, and Vitamin E, all of which reduce the risk of heart disease. The purpose of this project was to determine what type of material can show the most effective result of the ripening of an apple without the use of chemicals. In each trial, an apple slice was kept in three different types of materials. Each one was kept for four hours in a setting in which the heating was not operating. The results indicated that the control and cloth variable had a ripened mode with seven of the apples being ripened and three of the apples being unripened. The compostable plastic and paper had three apples which were ripened and seven apples which were unripened. The data did not support the hypothesis that if the apple slice was kept in paper, then the apple slice will ripen the most. The findings are not similar to the research, in which paper and plastic have shown to be effective in ripening. The results may have been more conclusive if more trials were conducted. A larger number of trials may have been needed for more accurate results. This is due to the fact that more trials reduce the effect of errors and increases the reliability of the results. As well as not cutting the apple. During the experiment, the experimenter cut the apples into slices rather than placing the whole apple in each material. Lastly, one factor which affected the results was the fact that the apples were not completely covered. This may have affected the results because the ethylene gas may not have been able to get trapped.

Aditi Kumar-The Effect of Different Amounts of Algaecide on Aquatic Plant Growth
George H. Moody Middle School

It was reported in 1939 that Lake Merritt’s water was taking on a rusty hue. The lake, as well as the bay it is connected to, lost marine life over time due to both natural and human influences. Scientists blamed an

invasion of microscopic sea organisms for the mass extinction in 1939. This was one of the first encounters of algae blooms. Algaecide is a substance regularly used to attack the algae in pools and aquariums. The chemical in algaecides could be linked to harming flora in natural water bodies. The goal of this investigation was to ascertain how different dosages of algaecide would impact the plant's height after 14 days. Plants in three different groups were treated with one milliliter of algaecide a day, three milliliters of algaecide a day, and no algaecide. Every plant was measured daily for the duration of the experiment. The data was analyzed, and the change of height in the plants from the first to the last day was used to calculate the results. The results showed that the plants from the group that received the most algaecide performed the best, with a mean decrease in height of 0.5 centimeters, and the plants from the control group that received no algaecide performed the worst, with a mean decrease in height of 13.225 centimeters. The hypothesis was that if the experimenter put more algaecide than one milliliter to one liter of water ratio, then the plants won't survive. The data did not support the hypothesis. There seems to be a clear relationship between the quantity of algaecide supplied and the health of the plant, based on the variations in height of the aquatic plants identified by this study. Increasing the algaecide dosage to reasonable levels can help the ecosystem thrive.

Plant Science & Microbiology B (MS PM-B)

First Place

Mital Eshaan - Effect of Turmeric on UVC-Induced damage in Mung Bean plants.
George H. Moody Middle School

UV radiation is damaging to skin health and is linked to skin problems such as skin cancer. Turmeric, due to its photosensitive properties, has the potential to be used against UV radiation. A few studies have shown that turmeric has a protective effect against UVA and UVB radiation. However, no studies using turmeric against UVC radiation have been completed. Therefore, this experiment investigated turmeric's effect on UVC radiation on mung bean seedlings. Mung bean seeds were soaked in water for 7 days for germination. Three seedlings were placed in each Petri dish with a total of 20 Petri dishes. Then, turmeric was soaked in olive oil and it was placed onto a gauze strip which was then placed 1 inch above the dishes. Another gauze was soaked in olive oil and put on top of the control group. The UVC ozone-free 36-watt lamp was then turned on and each day it was turned off and 2 mL of water was added to each petri dish. The mung bean plants were marked as dead based on their brown discoloration and then the number of days alive was recorded. The average and standard deviation number of the turmeric group was 7.1 (0.99) days compared to the non-turmeric group with 6.1 (0.88) days. An unpaired Students t-test showed that turmeric had a significant statistical difference from the control group ($t=2.39$ at $dF=18$; $p=0.03$). Therefore, the experiment showed that turmeric protects against UVC radiation with mung bean plants. For further study, the same experiment could be done with skin samples or other living models to determine if the protective effect can be increased and what turmeric amount is most effective. Turmeric could be used as a spread or paste that could block sun damage. This could be particularly effective in areas where sunscreen is less available.

Second Place

Lucian Pozzi - What Method is Better to Grow Stachys byzantine, a Hydroponics System or an Aquaponics System?
Sabot at Stony Point

This experiment was designed to determine the best growing method for the plant "Lambs Ear" also known

as "*Stachys byzantina*." During this experiment various growing systems were used including aquaponics and hydroponics. Potting soil, a traditional growing medium, was used to compare how effective the systems were in regard to overall growth of the plant. In order to conduct this experiment, the Lamb's Ear was cultivated from a local garden and brought to the University of Richmond Greenhouse for transplantation. All of the Lamb's Ear cuttings were similar in shape and size. Then, $\frac{1}{3}$ of the Lamb's Ear cuttings were transplanted to an aquaponics growing system. The next $\frac{1}{3}$ was wrapped in rock wool and put into a vertical hydroponic system. The last third of the plants were put in pots with soil. The plants were analyzed based on both height growth (in cm) and number of leaves. The final data showed that Lambs Ear is best grown in a hydroponics system, most likely because the method used to water the plant was able to be more closely controlled than the other growing systems. The experiment also showed that aquaponics is also viable to grow Lambs Ear. Both growing systems were shown to be significantly more effective than growing Lamb's Ear in soil.

Third Place

Ishaan Patankar -The Effect of Different Fertilizers on the Height of a *Trigonella foenum-graecum* over 14 days.

George H. Moody Middle School

This study aimed to investigate the effect of various fertilizers on the growth of *Trigonella foenum-graecum*. Different types of fertilizers, including Nitrate based, Phosphorus based, Potassium based, and Compost fertilizer, were applied to the plants in separate pots, with a control group consisting of regular ground soil. The height of the plants was measured in centimeters after 14 days, with the plants receiving the same amount of sun and water. The results showed that the Compost fertilizer was the most effective at stimulating plant growth, with an average height of 7.4 cm, compared to 5.2 cm for Nitrate based fertilizer, 4.8 cm for Potassium based fertilizer, and 2.6 cm for Phosphorus based fertilizer. The control group had an average height of 4.9 cm. The study also found that compost fertilizer is a great way to decrease waste by turning man-made waste into fertilizer and it is environmentally friendly. (Cameron-Hild, Joanne, 1990) The study also showed that Potassium based fertilizers improve plant disease resistance and play an important role in increasing crop yields and overall quality. Nitrate based fertilizers contain extra nitrates for plants, Phosphorus fertilizers are associated with a plant's ability to use and store energy, including the photosynthesis process. (The Fertilizer Institute editors, 2014) Overall, the findings of this study suggest that compost fertilizer is an effective alternative to traditional ground soils for promoting plant growth.

Honorable Mention

Shaivi Shankhwar -The Effect of Leftover Tea Leaves on *Coriandrum sativum* Germination Speed
George H. Moody Middle School

Deviations of tea from the *Camellia sinensis* have been created for centuries, with origins dating back from 206 B.C.-220 A.D. Globally, tea has proved to be a common beverage in numerous regions. However, with the global tea market possessing a value of \$229.3 billion USD (2022), the mass production and usage of tea is causing tea waste rates to continue to elevate, as well. The purpose of this research project was to identify ways to utilize tea waste in a household environment, specifically in terms of gardening, rather than having waste harm the community. This process was accomplished by examining the germination speed of *Coriandrum sativum*, most known as the simple coriander plant. Four plastic cups were placed by a windowsill, with four seeds planted 2.54 cm below surface level. Each cup was treated with water three of the five examination days and received tea waste at the levels of 4.93 g, 9.86 g, 14.79 g, and no tea waste received. After five days, the cups were inspected for germination identifications. The data was not supported by the research hypothesis that if the above levels of leftover tea leaves are applied to *Coriandrum sativum*, then the plant receiving 9.86 grams of tea leaves will have the most rapid germination. Of the ten trials in this experiment, it was concluded that seeds receiving 9.86 g of tea waste have the most rapid germination. Based on the provided research, receiving a moderate level of tea waste exhibited the best germination rates.

Honorable Mention

Sara Moussavi -The Effect of Different Types of Benzoyl Peroxide on Bacterial Growth.
Benton Middle School

Acne affects many young people, and there are many treatments for this condition, including benzoyl peroxide. Benzoyl peroxide is an accessible over-the-counter medication used to treat mild to moderate acne, and this product comes in different forms such as soap bars, cream, gel, and wash. Benzoyl peroxide may also come in different strengths, such as 5%, and 10%. The purpose of this experiment was to test whether different forms of benzoyl peroxide – such as a cream gel or wash – had different effects on bacterial growth on the skin. The hypothesis for this study was that if different types of benzoyl peroxide were used, then there would be a different effect on bacterial growth. In this study, a non-pathogenic Gram-positive bacterium, *Bacillus Subtilis*, was seeded onto the agar plates using a swab. A small amount of each type of benzoyl peroxide product was added to the plate, then the zone of inhibition (clearing of bacterial growth) was

measured to see how much bacteria grew around the where the benzoyl peroxide was placed. The results showed that the benzoyl peroxide face wash had the most antibacterial effect after 48 hours, and that all the products had a distinct difference in the zone of inhibition. In summary, using a 10% benzoyl peroxide face wash will decrease bacterial growth on the skin most effectively.

Honorable Mention

Aditi Vasudev -The Effect of Household Chemicals on the Growth of Chive Plants

George H. Moody Middle School

The annual global production of hazardous trash is around four hundred million tons, and one of the main reasons for this is household chemicals. A single household has more than sixty-two environmentally hazardous substances. Toxic vapors have grown to be a significant issue as well, primarily impacting humans along with hazardous trash. This experiment tested whether certain common home chemicals affected chive plant development in different ways. The independent variables used in this experiment were household chemicals, with levels of 3% hydrogen peroxide, soap, salt water, and distilled water serving as the control. The dependent variable was the chive plants' growth and how various chemicals affected the plants' height. It was hypothesized that salt water would harm chive plants the most. This was hypothesized since the experiment looked at how the different household pollutants would affect the detrimental influence on the chive's height. The hypothesis was supported according to the data, as trials treated with salt water had a mean height of zero centimeters, meaning none of the plants germinated and grew. Six t-tests were performed on the data recorded. It was found that the data was statistically significant between the levels of the independent variables and the null hypothesis was rejected. Even though two of the six t-tests did not have a value greater than the critical table value of 1.677, four of the t-tests did, showing that the independent variable was more likely to account for the independent variable and not chance or error. A possible explanation for why salt water is so detrimental for plants is that sodium and chloride ions can be harmful when they build up in plants, causing a chemical drought and preventing plants from absorbing nutrients.

Riyan Nayak - Effect of Type of Environment on Plant Height

George H. Moody Middle School

Around the times of 5000 BCE, a new plant had been found around the regions of the Middle East and Italy;

it was called coriander. At the time, it was used as a spice for bread and other food, but now, it is used for medicinal purposes and for its strong masking scent. We may now lose this plant due to the need for resources on Earth, and it could have an effect on our world. The purpose of this project is to find a pseudo-environment that could fit the need for coriander. There are four biomes: plains, savannah, forest, and rainforest. The hypothesis of the experiment is "If the environment for growing the coriander is the forest, then the group receiving those conditions will have the highest increase in plant height." This is because the biome has the in-between conditions of the Mediterranean and many gardening guides. Ten cups, each containing a soaked seed, is placed next to a window, where the amount of light and the amount of water given to the plant are varied. In the results, the best performing biome was the forest, with an average of 1.7 cm, respectively followed by savannah with a mean of 0.6 cm, plains with a mean of 0.5 cm, and the worst performing rainforest with a mean of 0.4 cm. All of the data was super clumped, with a standard deviation of 0.4 for all except for the plains, which had a standard deviation of 0.3, and the control, with a standard deviation of 0.8. This was most likely due to the problems of not giving the right amount of water. Not only is underwatering bad, but overwatering could also be even worse. This is why the rainforest ended up last. So, the hypothesis had matched the conclusion and the best environment is most likely the forest biome, affected by the idea of possible errors such as varying weather and non-precise measurements.

Aakash Parab -The Effect of Natural and Artificial Fertilizers on Soil pH
George H. Moody Middle School

Decreasing crop quality has been a major issue that negatively affects our nutritional health. (The Institute for Functional Medicine, 2020) One possible reason for this is the shift from natural to artificial fertilization of soil, which correlates with the drop in crop nutrition overtime. This shift happened because artificial fertilizer was and is much cheaper (Hergert et al., 2019) but as it is not natural it can disrupt natural processes such as the nitrogen cycle. (Pradhan, 2020) It may also affect soil quality, which this experiment attempts to prove. The experiment was conducted by growing pea plants and fertilizing them with artificial and natural fertilizers as well as a control group without fertilizer. Afterwards, the pH of the soil of each plant was tested to determine whether the fertilization method had an effect on the soil pH. Soil pH is a significant variable because it controls the amount of nutrients a plant can absorb in that soil, which affects the amount of nutrients that will end up in the plant itself. The ideal soil pH is somewhere in between 6 and 7, depending on the type of plant. The results of this experiment show that natural fertilizer, with a soil pH of 6.33, had the most ideal pH level compared to artificial fertilizer, with a soil pH of 5.805. This shows a strong correlation between artificial

fertilizer and poor soil pH, which affects the amount of nutrients a plant can absorb. This data is supported by the evidence which shows that organic crops generally are better nutritionally.

Aanchal Pate I-The Effect of Caffeine on *Nigella 68tyrofoam* Growth
George H. Moody Middle School

In Ethiopia, a goat herder made the first known discovery of coffee. Coffee eventually gained popularity, spreading faster and faster as more people learned about it. Caffeine left Ethiopia and traveled to the west before making its way to the Americas. Now, several centuries later, coffee is drunk by a whopping three-quarters of the U.S. population. A beverage this significant can also be found in other aspects of life, namely, agriculture. This study was conducted in the hope that it could potentially fuel experiments about the effect of caffeine on more important staples such as sweet corn, beans, and onions. All those vegetables are acid-loving, just like *Nigella damascena*, so there is a high chance that the study could be replicated and executed on different acidic fruits and vegetables. However, when the hypothesis was first written, it claimed the opposite to be true, thinking that the acidity from the caffeine would stunt the growth of the plant. All of the items for the experiment were purchased and set up the day before the investigation began. Finally, three weeks after it began, all of the groups were given water. Each group was given its solutions for the final two weeks and was observed until the experiment was completed. The average height of the plants fed 100% coffee was 6.02 in, compared to 5.17 in. for the plants given 50% diluted coffee, and 4.73 in. for the plants given water. After reviewing the data, it was determined that providing *Nigella damascena* plants with pure coffee produced the best outcomes, despite the fact that this did not support the research hypothesis.

Fenya Santosa -The Effect of Hydrogen Peroxide on the Germination Rate of Slow Bolt Cilantro (*Coriandrum sativum*)
George H. Moody Middle School

The widely used disinfectant hydrogen peroxide is now authorized by the EPA (Environmental Protection Agency) for use in treating microbiological pests on crops grown both indoors and outdoors, as well as on some crops after harvest. The purpose of this project is to really test the positive, neutral, or negative effects of hydrogen peroxide use on seeds, and specifically what level of hydrogen peroxide provides the best results. Twenty small bags, five for each level, were made, each with varying measurements of hydrogen

peroxide (control, low, medium, and high). Each was tested on how many seeds germinated each day and the physical attributes of each group. From studying, the results indicated that by day 9 of germination, the medium level (15 mL of H₂O₂), had 46 seeds germinated while also looking the most natural in terms of germination. Even though the high level (20 mL) had all the seeds germinated, it didn't look as natural and healthy as the medium level. Each level's estimated germination rates (to help the planter/farmer know the plant's potential for planting: $GP = \frac{\text{healthy seedlings}}{\text{total number of seeds}} \times 100$) in the end were: control-38%, low H₂O₂ level- 70%, medium H₂O₂ level- 92%, and high H₂O₂ level- 64%. These results support the prior hypothesis, "if I use 15 mL of hydrogen peroxide (medium level), then the seed germination rate will be the highest." Based on the results of different hydrogen peroxide levels tested on the germination of slow bolt cilantro, the medium level had the best effect on the germination of the seedlings. The results can also prove that the use of 15mL Hydrogen peroxide on germination can speed up germination while also providing healthy/healthier results.

Saharsh Darsh Shetty -The Effect of Biodegradable and Conventional Detergents on Plant Growth
George H. Moody Middle School

When laundry detergents run off into soil, their chemicals impact the environment. Biodegradable detergents are thought to harm the environment less than conventional detergents. This experiment was conducted to determine which detergent is least harmful to plant growth. The investigator hypothesized that if biodegradable detergent solutions were used to water plants, then those plants will grow taller than plants watered with conventional detergent solutions. In this experiment, 5%, 10% and 25% dilutions of conventional (Tide, Ariel, Gain) and biodegradable (Earth Breeze, EcoWise, 7th Generation) detergents were made with water. Fenugreek seeds were watered with these solutions over 12 days. Three trials using four seeds each were completed for each of the 18 dilutions. The number of sprouts and their heights for each detergent dilution were recorded, and the data was analyzed through a line graph. Fenugreek seeds watered with biodegradable detergent solutions grew 1-3 inches while plants watered with conventional detergents grew 0-1 inches. All dilutions of Ariel and Gain and the 10% and 25% dilutions of Tide completely prevented all plant growth. All biodegradable detergents permitted plant growth in their 5% and 10% solutions. Thus, it was concluded that biodegradable detergents stand up to their "eco-friendly" advertising because they are less harmful to plant growth.

Raymond Vickery -The Effect of Different Conditions on the Growth Rate of Succulents Sabot at Stony Point

The objective of this project was to determine the best method for growing the plant *Graptopetalum paraguayense*: hydroponics, aquaponics, or traditional soil methods. *Graptopetalum paraguayens* is a succulent plant. Succulents are plants that store water in their leaves and can therefore grow in arid conditions and they can “drink” from themselves. In order to conduct this experiment was to place four similar size and shape plants in each of the plants in different growing locations. The plants were all given the same amount of time to grow, were provided with the same amount of light, and had the same watering schedule. Hydroponics grows plants without soil. Chemical fertilizers are added to the system to provide the plants with nutrients. Aquaponics uses fish waste to provide nutrients to plants. This process also does not use soil. Both growing systems compared to the traditional way of growing succulents in soil. A key result was the increased growth of the plants in the hydroponics tower and in the aquaponics system when compared to plants grown in soil. The original hypothesis was that the aquaponics plants will grow the tallest because the nutrients simulate that of a real ecosystem as they are naturally produced by the fish that are part of the set-up. However, this hypothesis was not supported because the hydroponics system resulted in the most growth of the plant. Succulents store water in their leaves so using growing systems where the water is infused with nutrients may yield greater growth and should be further explored as a viable way to grow succulents while conserving water.

Waldman Isaac Waldman -The Effect of Common Sunscreen Chemicals on the Growth of Bean Plants Williamsburg Middle School

Decreasing crop quality has been a major issue that negatively affects our nutritional health. (The Institute for Functional Medicine, 2020) One possible reason for this is the shift from natural to artificial fertilization of soil, which correlates with the drop in crop nutrition over time. This shift happened because artificial fertilizer was and is much cheaper (Hergert et al., 2019) but as it is not natural it can disrupt natural processes such as the Nitrogen Cycle. (Pradhan, 2020) It may also affect soil quality, which this experiment attempts to prove. The experiment was conducted by growing pea plants and fertilizing them with artificial and natural fertilizers as well as a control group without fertilizer. Afterwards, the pH of the soil of each plant was tested to determine whether the fertilization method had an effect on the soil pH. Soil pH is a significant variable because in controls the amount of nutrients a plant can absorb in that soil, which affects the amount of

nutrients that will end up in the plant itself. The ideal soil pH is somewhere in-between 6 and 7, depending on the type of plant. The results of this experiment show that natural fertilizer, with a soil pH of 5.805. this shows a strong correlation between artificial fertilizer and poor soil pH, which affects the amount of nutrients a plant can absorb. This data is supported by the evidence which shows that organic crops generally are better nutritionally.

High School Sections

Botany A (HS BOT-A)

First Place

Virginia Academy of Science Botany Award

Bansi Bhimjiani-The Effect of Dietary Supplements on *Agrobacterium tumefaciens* in Pansies

Mills E. Godwin High School

The purpose of this experiment is to ascertain whether dietary supplements have an impact on the net growth of pansies that are infected with *Agrobacterium tumefaciens*. Over the past few decades, the bacteria *Agrobacterium tumefaciens* has become responsible for the tumor-producing crown-gall disease that affects dicots. It has the broadest range of hosts of all plant pathogenic bacteria and results in financial losses in agriculture. The four levels of the independent variable that were tested were 0.05000 mg of vitamin D₃, 7.500 mg of beta-carotene, 1,000. Mg of turmeric, no supplements (control), and each level had 13 trials. It was hypothesized that if vitamin D₃ supplements are provided to the pansies affected with *Agrobacterium tumefaciens*, then the pansies will have the highest net growth. In this experiment, the pansies' initial heights were recorded, and then the plants were injected with *Agrobacterium tumefaciens*. Dietary supplement solutions were created and provided to the plants. The final height of the pansies was recorded, and the net growth was calculated by subtracting the initial height from the final height. The results showed that vitamin D₃ allowed the plants to have the highest net growth whereas no supplements (control) yielded the least. T-tests demonstrated that the data sets were caused by the dietary supplements, not chance or error, and that there was an overall effect on the net growth in the pansies. The results support the research hypothesis and reject the null hypothesis. Additionally, the results acquired were due to vitamin D₃'s properties of stimulating cell apoptosis, reducing tumors, and more. Overall, this research could lead to further studies that investigate other dietary supplements in reducing cancers in monocots or even humans.

Second Place

Alba Edsall- The Effect of the Percentage of Polystyrene Microplastics in Soil on the Root Length of *Raphanus sativus* plants

Washington-Liberty

The purpose of this experiment was to determine the effect of the percentage of polystyrene microplastics in soil on

the root length of *Raphanus sativus* plants. The independent variable levels were 1%, 3%, and 5% microplastics while 0% microplastics was the control. The hypothesis stated that if *Raphanus sativus* plants are treated with different percentages of polystyrene microplastics in the soil, then those treated with no microplastics will have the greatest root length because microplastics reduce the ability of root crops to transport nutrients needed for growth. The hypothesis was not supported by the data because the plants treated with 1% polystyrene microplastics had the greatest root length growth over the 4-week period. Additionally, 3 t-tests determined that there was no statistical significance between the 0%, 3%, and 5% microplastic groups. However, an ANOVA test was performed and the p-value was 0.005. The p-value indicated that the data was statistically significant, and the null hypothesis was rejected. The null hypothesis stated that if *Raphanus sativus* plants are treated with different percentages of polystyrene microplastics, then there will be no difference in the root length between groups. Overall, the 1% microplastic group had the greatest root growth while the 0%, 3%, and 5% microplastic groups had no statistical effect on the growth. The results of this study indicate that further research is needed to understand the effects of microplastics on plant growth. Future studies could involve a longer experimental period, different types of microplastics, and smaller sizes of microplastics.

Third Place

Jacob Coleman- At What Acidity Level Does the Germination Rate of Pinto Bean Seeds Decline Below 50%?
Washington-Liberty High School

This experiment was conducted to determine at what acidity level do pinto bean seeds start to germinate at a rate below 50%. The pH levels tested were 2, 3, 4, 7 (control), and 10, with 10 being added as a reference to see how pinto bean seeds perform when exposed to an alkaline solution. The research hypothesis for this experiment is that if pinto bean seeds are grown with pH levels of 2, 3, and 4, then the germination rate of the pinto bean seeds will decline below 50% starting at a pH of 2, because prior research has shown once the seeds get to a pH of 2, it should be too acidic for above 50% to germinate. This experiment was conducted by germinating seeds in a petri dish then counting the number that germinated and measuring their root lengths. The main takeaways from this experiment were that all seeds groups germinated well above 50% except for the group with a pH of 10 (where none germinated), and the only acidic group to have a root length less than 13.50 cm was the group grown with a pH of 2, which averaged only 0.70 cm in length. This data suggest that acidic solutions don't significantly affect pinto bean seeds unless the pH of the solution is 2 or lower, since that is when the drop off in root length occurs, and that pinto bean seeds prefer acidic solutions to alkaline, since the alkaline group performed so poorly.

Honorable Mention

Manreet Cheema, Aahna Moreno & Laiba Siddique-The Effect of Arbuscular Mycorrhizal Fungi on Perennial Ryegrass and Flax Greens Grown in Soil with Varying Concentrations of Microplastics
Governor's School @ Innovation Park

Microplastics (MPs) are becoming more prominent in soil, causing negative effects on plant growth directly and indirectly. This study explored whether Arbuscular Mycorrhizal fungi (AMF), which is known to boost nutrient uptake in plants, can counteract the negative health effects of MPs on plants, by investigating the effect of adding AMF to the soil of perennial ryegrass (PR) and flax microgreens (FM) contaminated with MPs. Experimentation consisted of two main groups: PR and FM, each of which was split into five subsections (of 3 trials each): negative control, positive control, and three experimental trial sets of 2%, 4.5%, and 7% microplastics based on the soil mass, with 200 μL AMF per seed. The AMF did not have a noticeable effect on increasing the sprouting rates in the MPs groups, even though there was a significant difference in the sprouting rates ($p = 0$). However, the AMF had indications of having a positive effect on plant growth according to the max plant heights, especially for the PR, and the growth rates, which were significantly different between all PR groups ($p < 0.1$) and between the 4.5% and 7% FM groups ($p < 0.01$). Lastly, the high biomasses in the 7% FM and 4.5% PR groups compared to their respective control groups provide an indication of AMF positively affecting plant biomass. Future experimentation utilizing more trials, time, and AMF should be performed to determine the validity of the results and truly determine to what extent AMF can buffer the negative effects of microplastics.

Honorable Mention

Sarah Lawson Harrison- The Effect of Caffeine on the Growth and Development of *Glycine max*
Central Virginia Governor's School

The purpose of this study was to determine if caffeine had an effect on the growth and development rates of *Glycine max* (soybeans). The hypothesis was if soybeans are watered with different concentrations of caffeine, then the growth and development rates will initially increase in the 20 μM group, but if grown in higher concentrations of the caffeine, then the growth rate would be stunted. Three concentrations of caffeine were used in this study: a control with no added caffeine, 20 μM concentration, and 2000 μM concentration. Fifteen plants were grown per group for a growth period of 30 days. The groups were watered with their designated caffeine amount once a week and twice with water that contained no caffeine. Plant heights were measured in centimeters and biomass was measured in the roots, stems, and leaves of each plant. A one-way ANOVA determined significance in the heights with a p-value of 5.57×10^{-4} (alpha .05). A Tukey test showed the significance laid between the control and 2000 μM concentration. A two-way ANOVA was run for the biomass of the plants and had a p-value of 7.43×10^{-3} , which showed that there was a significant difference. A Tukey test found there was only significance between the biomass of the leaves in the 2000 μM

concentration and the control group and the 2000 and 20 μM concentrations. These results did not support the hypothesis; however, caffeine does have a significant effect on soybean growth and development.

Honorable Mention

Jamie Earsing- The Effect of Copper Pollution on Glycine Max
Central Virginia Governor's School

The purpose of this study was to determine whether or not copper had an effect on the biomass of soybeans. The plants were grown in a controlled environment, with increasing amounts of copper in each group (no copper, 100 ppm, 400 ppm) and separated by shoots and roots. After their growing period, the biomass was measured with a Pioneer scale and the averages of their mass was collected. The tests to determine significance of the data were the ANOVA single factor tests with all the data being statistically significant. The shoots had a p-value of .001 and the roots had a p-value of .035 with an alpha value of .05. The shoot group had two groups with significant data that was greater than the Dmin of .057. The root group had only one group with significant data that was greater than the Dmin of .05. Post-hoc Tukey Tests determined that the differences were between 400 ppm and the control group and 100 ppm and the control group for shoots, and 100 ppm and 400 ppm for roots. Therefore, the research hypothesis that if an excess of copper was added to the soil, then the soybeans biomass will increase, was supported by the data. In summary, heavy metals like copper that pollute the soil can cause changes in plant growth and disrupt the environment.

Parker Colasurdo-The Effect of Simulated Acid Rain on the Growth of Nitrogen-Fixing Clover Plants, Pre-Inoculated with Rhizobium Bacteria
Clover Hill High School

The purpose of this experiment was to determine if acid rain could have a negative effect on the height of nitrogen fixing plants and the Rhizobium bacteria that inoculates the plants. Nitrogen fixing plants are one of the only sources that organisms can get usable nitrogen from, and knowing what kind of effect acid rain has on nitrogen fixing plants can help scientists properly react. The three levels of independent variable were plants watered with pH 7.0 (control), plants watered with pH 6.0, and plants watered with pH 5.0. Ten pots each containing ten clover seeds were given to each pH group and had their height measured in millimeters using a ruler each week for a span of six weeks of growth. At the end of the experiment, the plants watered with pH 7.0 produced a mean height of 43.86 mm. The plants watered with pH 6.0 produced a mean height of 38.79 mm. The plants watered with pH 5.0 produced a mean height of 37.82 mm. After the data was collected, an ANOVA test was conducted to test if the data was statistically significant. After the results of the ANOVA test, the null hypothesis was rejected. The research hypothesis of this experiment was that nitrogen fixing plants pre-inoculated with bacteria when exposed to simulated acid rain (pH 5.0 and 4.0) would grow to

be shorter than the control (pH 7.0). The Research hypothesis was supported by the data collected at the end of the experiment.

Gretchen Gaffney-The Effect of Different Types of Magnesium on Calendula Plant Growth
Clover Hill High School

Environmental standards have been slowly dropping over the years as the world starts to lack specific nutrients needed for plants to survive and thrive. With the lack of nutrients comes a decline in plant growth and agricultural production. The element Magnesium specifically is vital for plant growth due to its being located in the center of chlorophyll. If different forms of Magnesium such as Magnesium sulfate, oxide, and glycinate are added to the soil of Calendula, pot marigold, plants then Magnesium glycinate would stunt plant growth the most while Magnesium Sulfate would enhance it the most. To execute the experiment, 70 pots were filled with soil, 10 of which had no added Magnesium. The other 60 were filled with soil mixed with the different amounts and types of Magnesium and were labeled accordingly (i.e. 500 mg Magnesium Sulfate, 1000 mg Magnesium Oxide, etc.). The Calendula seeds were placed underneath the surface of the soil and watered every other day. The seeds were measured every week to fully view the progress of the plants. The smaller amount, 500 mg, of each Magnesium compound did better than the larger amount, 1000 mg, however Magnesium sulfate enhanced the plant growth while Magnesium glycinate did not. Magnesium Oxide remained neutral, however both groups did a little worse than the control group. The research hypothesis was supported by the statistical test concluding that the null hypothesis can be rejected.

Landon Cosner-The Effect of Various Types of Homemade Fertilizer, Applied to Soil from Four Different Virginia Counties, on Pole Bean Plant Growth
Clover Hill High School

The purpose of this experiment was to determine the effect of different homemade fertilizers and Virginia soils on the growth of pole bean plants. Knowing which soil and fertilizer combination will benefit the residents of those counties by allowing them to efficiently grow the most plentiful harvest of pole bean plants possible. There were two independent variables, one with three levels and one with four. The two hypotheses were that coffee grounds in Chesterfield soil would have the most negative effect on the growth of the pole bean plant and pole bean plants grown in Goochland soil would provide the least amount of growth. The three independent variable levels for homemade fertilizer were coffee ground, eggshell, and banana peel fertilizer. The four independent variable levels for soil were Goochland, Chesterfield, Powhatan, and Amelia soil. Sixteen plants were grown at a time, four pots were filled with one pound of soil from each county. Fifteen grams of each homemade fertilizer was added to three different plant pots per county, and one pot per county with no fertilizer which was used as the control. A pole bean plant was planted in each plant

pot. After thirty days, the height and root length of the pole bean plants were recorded in a data table, and this process was repeated until each level had 10 complete trials. Chesterfield soil with coffee ground fertilizer produced the longest average root length of 64.480 centimeters. Chesterfield soil had the highest average root length at 33.820 cm. Coffee ground fertilizer had the highest average root length at 32.84 cm. Chesterfield soil and no fertilizer and Goochland soil with no fertilizer are nearly tied for longest stem. Chesterfield soil with no fertilizer produced an average stem length of 98.360 cm long. Goochland soil with no fertilizer produced an average stem length of 97.090 cm long. Goochland soil produced the highest average stem length at 86.510 cm. No fertilizer generated the highest average stem length at 84.410 cm. After the data was collected, two Two-Way ANOVA tests were conducted to test if the data was statistically significant. The results of each conducted Two-Way ANOVA test stated that the data was significant because the F value was greater than the F Critical value. Both null hypotheses were not rejected, and the data did not support the research hypothesis.

Kenneth Criss-The Effect of Different Roasts of Coffee Grounds, Added to Soil, on Cilantro Growth
Clover Hill High School

The purpose of this experiment was to determine the effect of different roasts of coffee grounds, added to soil, on cilantro growth. Knowing an environmentally friendly and inexpensive way to fertilize plants quickly allows individuals around the world to grow their plants effectively while not harming the environment. To measure the effects of different coffee grounds on cilantro, the cilantro plants were planted in soil and coffee grounds were added to each plant except for the control. A ruler was used to measure the growth of the plants on a weekly basis. The four levels of independent variable were control, light roast, medium roast, and dark roast. The heights were recorded in a data table where each level of independent variable had 20 complete trials. The control cilantro plants (no coffee grounds added) produced a mean height of 3.05 centimeters. The cilantro plants that experienced light roast coffee grounds had an average height of 2.98 centimeters. The cilantro plants with an additive of medium roast coffee grounds produced an average height of 0.00 centimeters. The cilantro plants where dark roast was added generated an average height of 1.47 centimeters. After the data was collected, an ANOVA test was conducted to test if the data was statistically significant. The p-value calculated was less than 0.05, so the null hypothesis was rejected. The hypothesis was: If coffee grounds were added to soil and the roast is lightened, then cilantro growth would be increased. The hypothesis was not supported because the control group of cilantros yielded the most growth, and the cilantro plants exposed to medium roast experienced less growth than the ones exposed to the dark roast.

Mishaal Haq-The Effect of Isopropyl Alcohol on Seed Scarification
Mills E. Godwin High School

The purpose of this experiment is to test the effect of isopropyl alcohol as a chemical scarification treatment on the

Wando pea plant in hopes of improving growth. Considering the significance of agriculture to our global civilization, this data would have significant real-world implications because growth can speed up by weeks with scarification, which presents more opportunities to focus on the quality of the plants as opposed to the quantity. The pea seeds were treated with a concentration of isopropyl alcohol and the first seed was exposed to isopropyl alcohol every day, the second was exposed every three days, the third was exposed every five days, and the last was not exposed and was the control. They were then measured daily for 10 days. It was hypothesized that if the pea seeds were exposed to isopropyl alcohol every three days, then they would grow the tallest. The results revealed that the seed without exposure to isopropyl grew the tallest, and the seed that was exposed every day was distinctively shorter. The t-test showed that the data was both significant and not significant. The seeds exposed every five days vs not exposed was not significant, but all the other t-tests were significant. The results did not support the 78tyrofoam hypothesis. This was probably because the scarification softened the seed coats excessively, which resulted in too much water being taken in, and the growth slowing down. Further studies should include chemical scarification with other accessible chemicals or varying concentrations of isopropyl alcohol.

Ayan Jethava -The Effect of Time in Magnetic Field on Dill Plant Growth
Mills E. Godwin High School

The purpose of this experiment was to determine the effects of magnetic field treatment on the growth of Dill plants. In recent years, magnetic field treatment has been proven to enhance the growth of certain plants such as salvia, calendula, etc. It is possible that magnetism has a similar effect on Dill. Dill plants were exposed to a magnetic field for 1, 2, or 3 weeks. Zero weeks in the magnetic field was used as a control for the experiment. These plants were allowed to grow for three weeks, and the plants were measured at one-week intervals. It was hypothesized that the longer a dill plant was exposed to a magnetic field, the faster it would grow. The results revealed that magnetic field treatment had little to no effect on the growth rate of dill plants. A t-test was done on the data, and it disclosed that the data was not significant for all possible comparisons of the IV levels. The results did not support the research hypothesis. It is believed that the results are due to the fact that the magnetic fields used were not strong enough to trigger protein synthesis within the plant. This research could lead to further studies that investigate how magnetic fields of different strengths affect dill plants as well as other plants of the same family.

Botany B (HS BOT-B)

First Place

Virginia Academy of Science Botany Award

Rohan Raman-The Effect of Varying Ratios of Bio-Enzymes Produced by Fermentation on Tomato Plant Height, Number of Leaves, and Weight of Fruit

Clover Hill High School

The question addressed in this experiment was whether varying concentrations of bio enzymes created through fermentation would affect the growth of plants. Current studies lack research on implementing bio enzymes on fruit bearing plants, such as the tomato plant, as well as bio enzyme implementation into soil stabilization and agriculture. The purpose of this experiment was to determine which concentration of bio enzymes would yield the greatest effects in terms of growth on tomato plants (*Solanum Lycopersicum*). The hypothesis stated that bio enzymes created through fermentation used on tomato plants would lead to a heavier weight of fruits, more leaves, and taller plants than those not treated at all. Ten trials of tomato plants for three different concentrations plus a control group were tested. The concentrations were 5 mL, 10 mL, and 20 mL of added bio enzyme. The crude bio enzyme solution was created through the fermentation of dried citrus and banana peels using a fermentation jar kit. Using a natural cane sugar called jaggery, the enzymes were able to activate, creating a sustainable and organic bio fertilizer. The bio enzyme concentrates were used on their respective plants once a week to ensure that the plants wouldn't receive too many nutrients. The highest means came from the 5 mL group for the number of leaves and height of plants, as the mean was 70.30 (hand counted) for the 5 mL leaf count group. For the plant heights, the mean was 32.557 cm for the 5 mL group. By the end of the experiment, not enough data was collected to show any results for the tomato masses. After the data was collected, an ANOVA test was conducted for each variable to test if the data was statistically significant. The results of the conducted tests stated that there was no statistically significant difference between the levels of independent variables because the p value was greater than the tested level of significance, 0.05.

Second Place

Andrew Wang- Effects of Transcription Factor WUSCHEL on the Regeneration of *Arabidopsis thaliana*

Blacksburg High School

As the global population and the food demand increase, the regeneration of modified crops with increased crop

production or enhanced resistance to various stresses became a promising approach. Plant regeneration is a critical step in producing GMOs (Genetically modified organisms). However, many crop species or current varieties in a crop are recalcitrant to regeneration. This study, using a model organism *Arabidopsis thaliana*, intends to test the effects of a transcription factor WUSCHEL in plant regeneration. Transgenic *Arabidopsis* plants with the expression of WUS controlled by an Estradiol-inducible promoter were used. The *Arabidopsis* seeds were grown on medium with or without Estradiol. The number of shoots formed in a SIM (Shoot Induction Medium) along with the growth and characteristics of the calli and plantlets were also examined. Student t-test was used to determine whether a statistically significant difference exists between the number of shoots formed in the absence or presence of Estradiol. *Arabidopsis* plantlets expressing WUS were observed to form larger and smoother calli and formed more and larger shoots but less and smaller roots than those not expressing WUS. The results indicated that the expression of WUS increases plant regeneration and can be employed for other crops.

Third Place

Chessa Lowery-Arbuscular Mycorrhizal Fungi as Plant Probiotics
Chesapeake Bay Governor's School

Globally, farmers who wish to generate the greatest crop yields for the greatest economic gain increase application of nutrient fertilizer across all agricultural sectors. As more nutrients are applied, crop yields respond with greater production, often with negative impacts of excess nutrient runoff that causes eutrophication of nearby waters. Arbuscular mycorrhizal fungi (AMF) are fungal microorganisms that form symbiotic relationships with plants by colonizing their roots. AMF acts as an extension of the plant's existing root system by releasing its own hyphae out from the roots farther into the soil to gather more available nutrients, including phosphorus. This study observes the effectiveness of AMF at harvesting nutrients for the plant host, acting as a probiotic source for nutrients, by looking at total, above ground, and below ground biomass in lettuce. This study utilized a head lettuce, where 24 seedlings were planted in 12 separate pots of similar size with 2 plants in each pot filled with topsoil with no added nutrients. Lettuce plants were harvested after 5 weeks and total, above, and below ground masses were compared. The biomass results showed that plant growth improved in all treatments relative to the control. The results showed that the presence of AMF significantly increased below ground plant biomass, demonstrating AMF's ability to unlock available phosphorus; however above ground biomass was not significantly increased. Increasing P uptake using AMF can reduce the amount of phosphorus pollution in the environment, decreasing phosphorus fertilizer inputs.

Honorable Mention

Isla Wearmouth-The Effect of Aquaponic Farming, in Comparison to Nitrate-Fertilized Soil, on the Growth of Lettuce Plants
Washington-Liberty High School

The widespread use of chemical fertilization in agriculture is becoming an increasingly prominent issue, and aquaponics may potentially provide a solution. Aquaponics is a type of agriculture that combines aquaculture and hydroponic farming methods. Plants and fish are grown for consumption in a symbiotic cycle where nitrogen-rich ammonia water is produced through fish waste which plants are then able to filter out of the water and use for growth. This experiment was conducted to determine if lettuce plants grown in aquaponic systems can grow to the same size or larger than lettuce plants grown in nitrate-fertilized soil. The hypothesis was: If the aquaponics system is used, then it will produce lettuce plants the same size or larger than plants grown using nitrate-fertilized soil because of the nitrates produced from ammonia in the aquarium water. Three agricultural groups included aquaponics, nitrate-fertilized soil, and organic soil (control). Lettuce seeds were germinated in petri dishes five days prior to placing them in their experimental groupings. The plants were then separated into the three agricultural groups and growth was observed for one month. Aquaponics had the highest mean height of 6.90cm and the largest total dry weight biomass of 0.03g. The hypothesis was supported because there was a significant difference between the mean heights of the aquaponic group and the nitrate-fertilized group. Nevertheless, it is important to recognize the scope of this experiment in relation to real world application, as future experiments of greater scale may produce more significant results. This area of study is greatly relevant in agriculture today and deserves research in the scientific community.

Honorable Mention

Ansh Patel-The Effect of Light Color on the Transpiration Rate of *Kalanchoe pinnata*
Clover Hill High School

The purpose of this experiment was to determine the effect of light color on the transpiration rate on the *Kalanchoe pinnata*. Knowing what color induces the highest transpiration rate allows plant growth to be more efficient and establishes a premise on which artificial light color to use in a location with an absence of sunlight. The hypothesis of this experiment was that plants under lighting on the higher side of the visible light spectrum such as red would yield greater transpiration rates for the *Kalanchoe pinnata*. This was not supported. To measure the transpiration rate, the plants were placed under each color of light for three hours. The hourly transpiration rate was determined with a potometer. The control which was sunlight had an average transpiration rate of 0.152 cm. The red lighting yielded an average transpiration rate of 0.244 cm. The yellow lighting produced an average transpiration rate of 0.198 cm. The green lighting resulted in an average transpiration rate of 0.160 cm. The blue lighting led to an average of 0.121 cm. The purple lighting had an average of 0.156 cm. After the results were gathered a One-Way ANOVA test was conducted to test the significance of the data. The results of the ANOVA test stated that there was no statistically significant difference between the levels of independent variables as the p-value was greater than the level of significance. The test concluded that the null hypothesis was not rejected.

Honorable Mention

Saanvi Sooda-The Effect of Household Fertilizers alongside Gibberellins on Fenugreek Height

Mills E. Godwin High School

The purpose of conducting this experiment was to test the effects of household fertilizers acting alongside gibberellic acid on fenugreek height. With the human population rapidly increasing, quicker and healthier methods of crop production using fertilizers are being explored internationally in order to keep our population fit and fed. Fenugreek seeds were watered with different household ingredient fertilizers (carbonated water and coffee) and gibberellic acid, a plant hormone that aids in growth. In order to effectively compare height, two controls were formulated: plants receiving only gibberellic acid and plants receiving no additives. All crops were kept in an insulated grow tent, watered with 50 milliliters of water weekly, and measured in height in centimeters weekly over 21 days. It was hypothesized that the plants receiving carbonated water alongside gibberellic acid would heighten the most. The collected data and results of the experiment revealed that the plants receiving carbonated water and gibberellic acid displayed the most advantageous growth comparatively. Using the data from week three, the final averages were calculated, displaying that plants receiving carbonated water and GA (9.3 cm) grew taller than those given coffee and GA (7.5 cm), only GA (8.8 cm), and only water with no additives (8.1 cm). This data supported the research hypothesis. Six t-tests were conducted and revealed that the data was statistically significant. It is believed that the results displayed these conclusions because carbonated water contains an abundance of macronutrients, enabling growth in plants, whereas growth from caffeine varies in different species of plants.

Aashay Mahajan-The Effect of Water Stress on the Weight of Poaceae

Mills E. Godwin High School

Across the world, many regions struggle with water supply and cannot spare much to survive. Agriculture accounts for most water usage annually, but what if it could be decreased? What if regions could still yield similar grass growth regardless of whether less water was used or not. This study was conducted in order to answer that question. It is imperative that this be researched because regions struggling with drought or water scarcity will consume less water while still having sufficient agricultural outcomes. Other areas that do not struggle with water scarcity can also implement this practice to decrease the overall use of water on grass in the world. This project was conducted by adding soil to fill $\frac{3}{4}$ of 100 plastic cups. Then, grass seeds of 2 brands were planted equally between the cups. From both brands, 25 cups were watered twice a day while the rest were watered once a day. It was hypothesized that both groups would yield the same amount of weight increase regardless of water stress. Watering the plants twice a day acted as the control as this is the recommended amount of times grass should be watered in a day. After collection of data, it showed that watering plants once a day yielded slightly lower growth than watering twice a day. Furthermore, t-tests revealed that the data was statistically significant. A possible explanation for the results is that plants are unaccustomed to drought and will grow less effectively.

Zainah Malik-The Effect of Different Fertilizers on the Growth of Hydroponic Basil Plants
Mills E. Godwin High School

This experiment was conducted to understand the effects of different additives to the growth of hydroponic basil. Growing plants hydroponically has helped gardeners consume less water and money, reduce risk of pests, and increase yield of plants. It also is a method independent from soil conditions, which can negatively affect the health of a plant if the soil is poor. This method can be utilized more in both home gardens and farms. Genovese basil seeds were grown in containers with different types of fertilizer. The plants were allowed to grow for a week and then their height was measured. The control in this experiment was a container with no fertilizer. It was hypothesized that basil plants treated with chemical fertilizer would grow the tallest. The results showed that plants that were not treated with fertilizer grew, on average, the most. A t-test was performed on the data and revealed that the data for the Chemical fertilizer vs Control, Compost fertilizer vs Control, and Compost vs Tea fertilizer was significant, but not for Tea vs Control, Chemical vs Compost, and Chemical vs Tea. The results did not support the research hypothesis. This is due to an imbalance of nutrients in the fertilized plants, which could have stunted their growth. The ideal concentration of nutrients such as nitrogen, potassium, and phosphorus for optimum basil plant growth and how these fertilizers may affect other herbs can be studied in the future.

Tanvi Nareddy-The Effect of Water Conductivity on *Vigna radiata* Germination Speed
Mills E. Godwin High School

The quality of agriculture, ecosystems, and organisms are all based on the way natural resources are managed. One specific factor that impacts water quality is road salt. This salt can be washed into bodies of water, through storms, therefore increasing in streams, lakes, and oceans. The purpose of this study is to see if the water from effected streams and lakes, has an impact on the germination speed of *Vigna Radiata* seeds. The hypothesis of this experiment was: if a water conductivity of 500.0 $\mu\text{S}/\text{cm}$ is used, then the *Vigna radiata* will germinate the fastest. Seeds were soaked for 24 hours in different water conductivities: 1.0 $\mu\text{S}/\text{cm}$, 500.0 $\mu\text{S}/\text{cm}$, 1,000.0 $\mu\text{S}/\text{cm}$, 10,000.0 $\mu\text{S}/\text{cm}$, and 55,000.0 $\mu\text{S}/\text{cm}$, 0.0 $\mu\text{S}/\text{cm}$. The seeds were enclosed in a damp paper towel then placed into a resealable bag. The control for this experiment was 0.0 $\mu\text{S}/\text{cm}$ as it is the conductivity of distilled water. The statistical test used to analyze the data was a t-test and the experiment supports that the null hypothesis was rejected, except for 1,000 $\mu\text{S}/\text{cm}$ vs. 1 $\mu\text{S}/\text{cm}$ and 500 $\mu\text{S}/\text{cm}$ vs. 1,000 $\mu\text{S}/\text{cm}$. This indicates the data was significant. This experiment supported that salinity directly affects the ability of the plant to absorb water, in a negative way, which is known as osmotic stress. Due to this, the seeds must absorb from the seed wall through diffusion and capillary action, which makes the process more difficult, because the seed normally can absorb water.

Siddarth Siddabattula -The Effect of Mycorrhiza Concentration on Soil
Mills E. Godwin High School

The purpose of this experiment is to find the effect of mycorrhiza concentration on concentration of nitrogen and potassium in soil. It was hypothesized that the highest concentration, 9g, would yield the highest amount of soil nutrients. The results of this experiment would help plant growers and farmers all around the world as arbuscular mycorrhiza is a widely used plant supplement. It would mostly help people with smaller soil amounts. To set up the experiment, small containers were filled with soil and mycorrhiza before the plants were placed in them. They were grown for 4 weeks while being tended to with water and sunlight, and after this, the soil was tested with a test kit returning a rating from 1 to 5, 1 being depleted in nutrients, and 5 meaning surplus. There were 4 groups: 0g, 3g, 6g, and 9g of mycorrhiza, with 0g as the control. The data showed a direct relationship (least nutrients in 0g group and increasing nutrients to 9g group) between the 2 variables and all the data was found to be significant, meaning the results were caused by the independent variables. The reason for these results is that mycorrhiza forms a symbiotic relationship with the plant, and the more the plant helps the mycorrhiza, the more the mycorrhiza helps the plant. It releases enzymes into the soil which create nutrients for the plant to absorb. The plant, in return, releases other nutrients for the mycorrhiza fungus to continue surviving with the plant's roots.

Sudarshan Srinaiyer-The Effect of Different Light Intensities on *Raphanus sativus* Plant Growth
Mills E. Godwin High School

The purpose of this experiment was to see how different light intensities affect *Raphanaus Sativus* (radish) plant growth. With many farmers switching to indoor farming to grow crops, this research could be extremely useful to find the best light intensity to grow radish plants, a common crop. This could lead to many farmers making a greater profit growing radish. A control was added to see how the radish plants would grow when given the normal light intensity of sunlight. The radish plants were treated with 1000 FC, 1250 FC, 1500 FC, 1750, and 2000 FC of light. A research hypothesis was formulated that if 1500 FC of light was used to treat the *Raphanus Sativus* plants, then they will grow to be the heaviest. The control group in this experiment was 1500 FC of light. The results of the control group were used as a baseline to compare the results of different IV levels. The results of the study indicated that the radish plants preferred 1750 FC of light. A t-test was performed on the data and it was found that the data is statistically significant. The results of the experiment did not support the research hypothesis which predicted that 1500 FC would be most effective in growing the radish plants. The results are likely due to radish plants preferring more amounts of light compared to other crops. However, too much light intensity can be harmful. Therefore, it showed a preference for the 1750 FC of light.

Jacob Tasker-The Effect of Inorganic and Organic Fertilizers on *Glycine max* Biomass and Nutrient Composition
Central Virginia Governor's School

The purpose of this study was to examine the effect of organic and inorganic fertilizers on *Glycine max* nutritional composition and biomass. The study was held at a local school for a four-week period of early October to late November of 2022. The plants were given the same soil and separated by the specific fertilizer that they were given. All groups were watered as needed rather than a certain schedule, and they were all given a 12 hour on -12 hour off light schedule. After data was collected on biomass and nutrient composition test results were gathered from the lab that tested them, a one-way Anova was run in Excel for biomass that resulted in a p-value of .001, which meant that with the Alpha value of .05, there was significance. With relation to nutritional composition, a two-way Anova was ran that resulted in a p-value of .00126, which was also significant with the .05 alpha. Due to the significance from both parts of the results two post-hoc Tukey tests were run which showed significance with the Vermicompost in nutrient composition and NPK in biomass. In the end, the research hypothesis was partially correct with relation to organic fertilizers having the greatest impact on nutrients and the study resulted in significance in both the fertilizers effect on biomass and nutritional composition.

Chemistry A (HS CHM-A)

First Place

Rodney C. Berry Chemistry Award

Abby Goff – A Comparison of the Durability of Commercial Glues and a Wheat Protein-Based Adhesive

Central Virginia Governor's School

The purpose of the study was to create a sustainable alternative to commercial adhesives out of wheat protein. The wheat protein was denatured in boiling water and then drained. The remaining substance was then applied to index cards and separated with a Vernier Structures & Materials Tester to test the force needed to separate the cards. A one-way ANOVA compared the average forces of separation of the wheat-based adhesive and two commercial adhesives, Elmer's and Krazy Glue. It provided a p-value of 1.881×10^{-5} that was compared with an alpha of .05, revealing significance between the groups. A post-hoc Tukey test located this significance between Krazy Glue and the other two, showing that it was considerably weaker on paper. There was no significant difference between the wheat-based adhesive and Elmer's, however, which demonstrated its comparability. The research hypothesis, which predicted that the wheat-based adhesive would be stronger than the Krazy Glue and weaker than the Elmer's, was not supported. Regardless, the results showed that the wheat-based adhesive performed well against the two commercial adhesives and that it has potential to be a widely used paper adhesive.

Second Place

Dylan Dickerson -The Effect of the Protein/Sugar Ratio on the Browning of the Maillard Reaction in Cakes Baked with Whey Protein

Clover Hill High School

The purpose of this experiment was to determine which protein to sugar mass ratio would most increase the browning effect of the Maillard reaction in cakes baked with whey protein. The creation of brown pigmentation is directly related to the creation of flavor and aromatic compounds. To measure the degree of browning, cakes with varying amounts of whey protein powder and sugar were baked. An app called Color Grab was used to measure the color of the cakes. The tested ratios were 10% protein to 90% sugar, 25% protein to 75% sugar, 50% protein to 50% sugar, 75% protein to 25% sugar, and 90% protein to 10% sugar. Thirty cakes were baked for each ratio, and the results were recorded in a data table. The cakes baked with a 10% protein to 90% sugar ratio had an RGB value of 132.1, 84.0, 53.1 on average. The cakes baked with a 25% to 75% ratio had a mean RGB value of 101.0, 49.5, 29.5. The 50% to 50% ratio had an average RGB value of 98.8, 56.9, 39.0. The average RGB value of the 75% to 25% ratio was 107.2, 65.5, 44.6.

The cakes baked with a 10% protein to 90% sugar ratio had a mean RGB value of 114.8, 73.5, 53.0. After the data was collected, separate ANOVA tests were performed for the R, G, and B values of the data set. The results of the ANOVA tests concluded that there was a statistically significant difference between the ratios because each p value was less than the level of significance. The hypothesis was that a 50% protein to 50% sugar ratio would have the highest degree of browning. The hypothesis was partially supported by the data, since the ratios with the most browning, 50% to 50% and 25% to 75%, had similar results.

Third Place

Anna Freeman -The Effect of the Amount of Gelling Agent on both Vegan and Non-Vegan Marshmallows
Washington-Liberty High School

This experiment was conducted to find how the amount of gelling agent affects the density of both vegan and non-vegan marshmallows. The levels of the independent variable in this experiment included double gelatin, half gelatin, and the control (full gelatin). The same levels of the independent variable were tested with carrageenan instead of gelatin, for the vegan marshmallows. Each level of the independent variable was tested twice, to minimize random error. The research hypothesis for this experiment was that if both vegan and non-vegan marshmallows are made with different amounts of gelling agents, then the non-vegan marshmallows with double the amount of gelatin will be the least dense, because if there isn't enough sugar in the gelatin-to-sugar ratio then the marshmallows will be more gooey and less dense, because sugar encourages gelatin to form shorter protein chains. Shorter protein chains make the marshmallows stiffer, and since the sugar stays constant while the gelatin doubles, the gelatin-to-sugar ratio will be off, leading to gooier and less dense marshmallows. This hypothesis was partially accepted, because the gelatin double marshmallows were the least dense, but it was not because of the gelatin-to-sugar ratio. Statistical tests (both ANOVA and t tests) lead to the conclusion that the data was statistically significant. The overall trend of the data suggested that if more gelling agent is added to marshmallows, then the marshmallows will be less dense. The opposite was also true, with marshmallows with less gelling agent being denser. This was the same for both vegan and non-vegan marshmallows.

Honorable Mention

Kate Floom -The Effect of the Amount of Red 40 in a Beverage on the Relative Luminance of the Substance
Washington-Liberty High School

This experiment was conducted to determine if there is a direct relationship between the amount of Red 40 in a beverage and the relative luminance of that substance. Studies have shown that consuming Red 40 can be detrimental to the health of the consumer, especially if they are a child. If a relationship existed, it would allow the customer to

choose the healthier option by observing how dark the different choices are. The hypothesis was that, if the substance has more Red 40, it will have a lower relative luminance. The prediction was tested by soaking pieces of white fabric in different beverages containing Red 40, then measuring the relative luminance of each fabric piece with the Colorimeter X app for iPhone. The results of this experiment showed that Kool-Aid—which had the most Red 40 (52.3 milligrams) —had the lowest relative luminance (35), and water—which had no Red 40—had the highest relative luminance (72). Faygo Redpop had the second-lowest relative luminance (41), then Gatorade (45), followed by Powerade (46). However, Faygo Redpop—which had 34.2 milligrams of Red 40—and Gatorade—which had 3.2 milligrams of Red 40—had no significant difference in relative luminance. The results of the experiment were inconclusive because of flaws in the experimental design.

Honorable Mention

Shangwen Cheng-The Effect of Natural vs Synthetic Dye on Color Intensity on the Violet Wavelength
Arlington Tech

The intent of this experiment was to determine the intensity of color on the violet wavelength in fabric dyed with natural and synthetic dyes. The plant-based natural dyes were extracted from blackberries, grape peels, and powdered *Indigofera tinctoria*, while the synthetic dyes were RIT dye and a 1.0% crystal violet solution in water. All were applied to 2 cm² white muslin cotton, with undyed pieces as control. Since dyes vary in sustainability and environmental impact, this experiment aims to determine the visual effect that natural and synthetic dyes have, to better understand how they can best be utilized in order to maximize safe and sustainable use. Purple dyes have a long history with humankind, having been in use naturally longer than recorded history, and being the first color to be synthesized in 1865. Thus, purple, specifically the wavelength 400, was chosen as a constant between dyes. The dyes were applied to fabric and tested in a spectrophotometer for transmittance percentage. It was hypothesized that if a fabric was dyed with synthetic dyes, it would show greater color intensity than if it was dyed with natural dyes, due to being specifically developed for the purpose of imparting color to the fabric. Overall, the RIT dye had the highest average transmittance percentage, followed by blackberry dye and indigo. Next was the control, crystal violet, and finally the grape peel. There are many reasons that the samples gave the results that they did, however, the likeliest suspect is simply human error, and the hypothesis was rejected.

Honorable Mention

Sophia Vekony-Electrophoresis: Building a Chamber for Identifying DNA
Wakefield High School

In this experiment, the objective was to investigate gel electrophoresis, which is a method that biologists use to separate

distinct DNA, RNA, or protein fragments. This was done by constructing a gel electrophoresis chamber, which was then used to discover how many components are present in various food coloring dye colors. In sum, an electrophoresis chamber was constructed through creating a circuit by connecting 9-volt batteries to steel wire submerged into a gel made of agar powder, water, and baking soda. Following, the three colors of food dye (yellow, blue, and green) were placed into wells and observed over 45 minutes, until there was noticeable migration and separation of the food coloring dye. Finally, each food coloring dye sample was compared and observed how many bands were formed and how far they migrated. The resulting data collected argued that the yellow food dye migrated the farthest (2 cm), and the yellow and blue food dyes both ended with 3 bands. In conclusion, the color of food dye affects the resulting migration and number of bands created through electrophoresis, simulating the effect of this process when DNA is used.

Zahra Akbar -The Effect of Active Carbon on the Amount of Chlorine Present in Water
Mills E. Godwin High School

The purpose of this study was to determine the most optimal concentration of active carbon to absorb and reduce chlorine. Chlorine, a substance commonly used for disinfection, can create harmful DBPs which pose health risks to organisms that receive chlorinated water. Active carbon can minimize these risks due to its high adsorption capacity and ability to reduce chlorine through catalytic reduction. The hypothesis stated that if 5.0 g of active carbon was exposed to 350 mL of contaminated water, the reduction in chlorine would be the most significant. A control group with no activated carbon was used as a comparison for the experimental groups. Containers were split into 4 groups containing 25 cups each. Then, 350 mL of water, 9 drops of bleach (10 ppm), and filter bags containing active carbon were added to each of the trials in their respective groups. The control group had a mean of 9.8 ppm, 1.0 g had a mean of 4.7 ppm, 3.0 g had a mean of 3.7 ppm, and 5.0 g had a mean 3.1 ppm. In total, 5 out of 6 t-tests showed statistical significance as they had a value greater than the table value (2.682). The t-test between the 3.0 g and 5.0 g groups was not statistically significant. In conclusion, 3.0 g was found to be the most optimal active carbon concentration. This was because the 3.0 g group provided adequate surface area and porosity to reduce chlorine, minimizing the efficiency of adding more carbon.

Tara Chahil -The Effect of Different Natural Juices Based on pH, on the Electrolyte Concentration
Washington-Liberty High School

Electrolyte and pH imbalances significantly affect the wellbeing of athletes or people that perform strenuous activities on a day-to-day basis. The purpose of this experiment was to determine the effect of differing pH juices on the amount of electrolyte the juices contained. The types of juices used were lemon juice (pH of 3), broccoli juice (pH of 8), and watermelon juice (pH of 5). It was hypothesized that lemon juice would have the highest concentration of electrolytes

due to the high acidity and ability to conduct electricity. The experiment was conducted by creating a conductivity sensor using straw and copper wire. The sensor was then connected to a multimeter device, and the sensor was then dipped into the differing juices. The multimeter device projected a number which was calculated to find electrolyte concentration using a variation of ohm's law. The results showed that lemon juice had the greatest electrolyte concentration with a mean of 0.597 S. On the other hand, distilled water, which was the control, had the lowest electrolyte concentration with a mean of 0.058 S. The data collected showed that lemon juice was the best juice in terms of electrolyte concentration. Though the data does not show a clear relationship between pH and electrolytes.

Maggie Bodman -The Effect of Polaroid Photo Development Temperature on Speed at Which Photos Reach Full Saturation
Clover Hill High School

The purpose of this experiment was to determine which climate is most efficient to take and develop polaroids in. The original hypothesis was that the amount of time the polaroids would take to become fully saturated would increase with a decrease of temperature during development. The development time was measured by placing individual polaroids into water of different temperatures (20°C, 10°C, and 45°C), and timing how long each polaroid took to reach its fully saturated shade. For the control polaroid, one container was filled with 200 mL of water at 20 degrees Celsius. The water was heated/cooled with the temperature-controlled faucet and then the FUJIFILM camera was held lens side down on the towel and the control polaroid was taken (without flash). The polaroid was placed back side down in the room temperature container at 20 degrees Celsius to fully develop for 20 minutes. After 20 minutes, the app "ColorSnap Visualizer by The Sherwin-Williams Company" was used on an iPhone to quantitatively measure the fully saturated shade, still wet. Another polaroid was then taken with the same procedure, but this time the amount of time it took for the level of saturation to quantitatively match the control polaroid (taking the polaroid out every 30 sec) was timed with a stopwatch and recorded. This procedure was repeated thirty times for 20, 10, and 45 degrees Celsius. The major findings of the experiment were that as the development temperature increased, the time it took for the polaroids to fully develop decreased. The average development times for 20°C, 10°C, and 45°C were 8.17 minutes, 14.88 minutes, and 2.00 minutes respectively. The polaroids developed in 45°C reached full saturation significantly faster than the polaroids that were developed in 20°C and 10°C. The research hypothesis was supported by the data. The null hypothesis of no significant difference was tested using a One-Way ANOVA test and was rejected.

Andrew Cairns -The Effect of Various Materials Used in the Composition of Golf Balls on the Distance the Ball Travels, When Putted
Clover Hill High School

The purpose of this experiment was to determine whether golf balls made with a trionomer or ionomer cover would roll farther when putt, compared to golf balls made with a urethane cover or other cover material. The hypothesis was: Trionomer/ionomer covers would result in the greatest distance, when a golf ball was putt. To perform the experiment, golf balls of various cover materials were collected, and used as the independent variable in tests. A simple machine to consistently putt the golf balls was created using wood. A flat putting green was found at a local golf club to record data for the experiment. Each of the five golf balls tested were putt 30 times with the simple machine, and the distance that the balls traveled was recorded in meters. The principal results of the experiment showed that the Callaway Hex Soft golf ball, made with a trionomer cover, rolled the farthest when putt, and the Srixon Q-Star golf ball, made with an ionomer cover, rolled the second-farthest. A one-way ANOVA statistical analysis test was performed, and the null hypothesis was rejected. The data supported the research hypothesis.

Shriya Bandla -The Effect of Different NPK Fertilizers on Sunflower Growth
Mills E. Godwin High School

The purpose of this experiment was to find the effects of different NPK fertilizer macromolecule ratios on sunflower growth. Lately, farmers have used NPK fertilizers as an additive to crops. NPK fertilizers consist of 3 main elements: nitrogen, phosphorus, and potassium. These macromolecules ensure that plants are grown in a fertile environment. In the experiment, sunflower plants (*Helianthus annuus*) were grown for 7 days, and the height was measured. The plants were treated with five grams of 46-0-0 NPK fertilizer, 0-46-0 NPK fertilizer, and 0-0-46 NPK fertilizer. The control used in the experiment are plants grown with no NPK fertilizer. The plants were grown for 3 more days, and the height was measured in centimeters using a ruler. To ensure the experiment was not affected by confounding variables, the same amount of sunlight, water, and soil was given to the plants. It was hypothesized that sunflower plants treated with 0-0-46 NPK fertilizer will grow the tallest. The results show that on average, plants with added potassium fertilizer grew 0.76 cm more than the plants with nitrogen-based fertilizer, 0.37 cm more than the plants with phosphorus fertilizer, and 1.29 cm greater than the control. The results imply the research hypothesis is supported. A t-test was performed on the data, and it revealed that the results are due to the independent variable. The results imply that sunflower plants favor potassium fertilizer the most since it grew the best. Further studies can examine the relationship between the different NPK fertilizer macromolecule ratios on the height of other commonly produced crops.

Liana Dillon -The Effect of Several Methods of Water Treatment (Boiling and Activated Alumina) on Resultant Fluoride Levels in Fluoridated Tap Water
Clover Hill High School

This experiment was conducted with the intention of determining which of the stated methods of water treatment is the

most effective at filtering out fluoride (measured in parts per million). The research hypothesis was: If boiling and activated alumina were used to treat fluoridated tap water, activated alumina would decrease the fluoride concentration of the water the most. Water samples were taken from the unfiltered tap, and their fluoride content was measured using a fluoride colorimeter. Then, the chosen method of water treatment was applied to the water (boiling, activated alumina, or nothing for the control group). After the selected amount of time, the water was tested again for its fluoride concentration (ppm) following the treatment or lack thereof. This process was repeated 30 times for each form of water treatment. The mean, as the noted measure of central tendency, did not differ and remained 0.2 for all methods of water treatment. It was found that none of the methods of water treatment displayed any significant differences from each other, and there were no clear trends within the data. The experiment was determined to be insignificant. In future experiments with similarity to this one, it is recommended that great care is taken in testing and the recording of results. Furthermore, the optimal uptake capacity of the activated alumina and water should be researched further to obtain the proportionally ideal amount of activated alumina. The null hypothesis was not rejected. The research hypothesis was not supported, because the data showed no significant trends or differences between the different methods of water treatment or absence thereof (boiled water, unfluoridated bottled water, untreated tap water, and water treated with activated alumina).

Emma Ebel – Testing Hand Sanitizer Alcohol Levels with Gas Chromatography
Southwest Virginia Governor’s School

Do brands actually tell the truth about what’s inside their products, specifically hand sanitizer? This project looks at five different hand sanitizer brands and tests their alcohol makeup using gas chromatography with a proprietary chemosensor. The hand sanitizer brands tested were Bath and Body works, Faber Distilling Co., Honest Co., “Dish”, and everyone for everybody. The expressed isopropyl alcohol content for each hand sanitizer were: 72%, 80%, 62%, 62%, and 62%. The hand sanitizers were mixed with n-butanol in a 10.0 mL solution. 7.0 mL of the solutions were the hand sanitizers, and the other 3.0 mL was butanol. The hand sanitizers were all tested a total of 6 times each using the *Go Direct Mini GC* by the brand Vernier while injecting 2.0 μL per test. My null hypothesis for this experiment was that when testing the alcohol levels of the hand sanitizers, the content level found will be moderately close to what is expressed on the bottle, with the exception of outliers. The alternative hypothesis was that when finding the alcohol content of the hand sanitizers, the found level would not match the actual value, due to unknown entities in the ingredients. Since the p-values found for all 5 of the hand sanitizers were greater than 0.05, we fail to reject the null. There is not enough evidence to support a difference in the given vs. found values of the hand sanitizer isopropyl alcohol content.

Chemistry B (HS CHM-B)

First Place

Rodney C. Berry Chemistry Award

Rina Kopylev – The Effect of Candle Wax Material on Burn Rate and Soot Production

Washington-Liberty High School

Throughout the last several millennia, candles have played a very significant role in human lives. Today, many different substances are used to produce wax, some of them producing soot that is harmful to human health. This experiment explored the properties of palm, paraffin, soy, and beeswax. This experiment investigated the effect of candle wax material on burn rate and soot production. It was hypothesized that different wax materials would have different burn rates and soot production, and that palm wax would have the lowest burn rate as well as least soot production due to the fact that it has the lowest density. Two candles of each wax were purchased, five trials were performed on each group, for a total of ten burn rate measurements per wax type. Soot production was recorded qualitatively using photographs. The results did not support the hypothesis, instead the results suggested soy wax and beeswax had the lowest burn rate and least soot production. There was a statistically significant difference between paraffin and palm versus soy and beeswax, but not within either of the pairs. This experiment helped expand studies of candle wax and helped to determine what kind of wax material makes for safer candles.

Second Place

Amelia Uhl-The Effect of Price on Microplastic Content in Water Bottles

Central Virginia Governor's School

The purpose of this study was to determine the effect of disposable plastic water bottle prices on the number of microplastics within the contained water. Six different brands were tested throughout the experiment, and eight, 16.9 fl oz samples were tested for each. Three brands tested were sold for a lower price, including Great Value (0.9¢/fl oz), Pure life (1.0¢/fl oz), Deer Park (1.7¢/fl oz), and three for a higher price, including Evian (7.9¢/fl oz), Voss (33.3¢/fl oz), Fiji (7.6¢/fl oz). Each sample was poured over grid filter paper placed inside a glass funnel and was filtered through the funnel using an air vacuum. This filter paper was then evaluated under a microscope and the number of microplastic particles per sample was recorded using tally marks. The results showed a significant difference between the observed and expected microplastic particle values, and the three lowest-priced brands contained the highest number of microplastics, while the three highest-priced brands contained the lowest. A chi-square goodness of fit statistical analysis was run to determine a p-value of 1.51×10^{-05} , allowing the null to be rejected using an alpha value of .05. The research hypothesis, stating an increase in price will result in a decrease of microplastics, was supported. This

research showed significance between water bottle price and number of microplastic particles, where reduced prices resulted in increased microplastic content and increased prices resulted in decreased microplastic content.

Third Place

Eden Mitchell – Differences in the Presence of Aluminum, Lead, and Arsenic in Foundation for Various Skin Shades
Southwest Virginia Governor's School

The cosmetics industry is one of the largest businesses in the world that attracts approximately 160 million women in the United States alone each year. With such a large number of consumers purchasing cosmetic products, the Federal Drug and Food Administration has strict regulations and guidelines. Though these exist, they are not always followed and consumers are often exposed to hazardous chemicals. Studies have shown that women of color, Latinos, and Hispanics are disproportionately exposed to harmful ingredients in their cosmetics. Some of these dangerous chemicals include aluminum, arsenic, iron, and lead. This research project wanted to determine if there was a difference in concentration of these four chemicals between various foundation shades to help demonstrate that there is lingering ethnic inequalities within the cosmetic industry. In this research, five different shades from the brand Juice Beauty were tested for their chemical concentrations. Three samples of each shade were tested. Aluminum, arsenic, iron, and lead were extracted from the foundation by adding 1 mL of hydrochloric acid (HCl) and 3 mL of nitric acid (HNO₃) to the formula and then running them through a microwave digester, which was set at 175 °C for four and a half minutes and then held at the same temperature for five. All fifteen samples were then placed into the Inductively Coupled Plasma (ICP) instrument at various wavelengths that corresponded to the four chemicals being tested. All data was generated by the ICP and then an ANOVA statistical analysis test was performed. The concentrations of aluminum, arsenic, and lead were all below the lower limit of detection for the ICP, so only a statistical analysis was conducted on iron. The p-value for this was 0.0037. The p-value is less than the level of significance, which was set at 0.05 prior to any testing. The results for this experiment support the alternate hypothesis. A follow up Tukey Honestly Significant Difference test was also performed and demonstrated that there was a significant difference between shade 5 and all of the other shades, except for shade 4. No other shades had a significant difference between each other. Future research is needed to determine if the concentration of other elements vary within foundation, as well as the brands in which this difference can be found.

Honorable Mention

Arianna Hellman -The Effect of Different Methods of Insulation and Cooking on the Height of Cake Domes
Washington-Liberty High School

The purpose of this experiment was to test the effects of different methods of insulation and baking on the convexity

of cakes, with the intent of finding the most effective method to reduce the convexity. Obtaining level cakes is crucial when layering them to ensure both the structural integrity and overall aesthetics of the cake. The research hypothesis for this experiment was that the cakes baked in a water bath will yield the most level cakes out of the methods tested because it will be the most successful in evening out the heat distribution during baking. This creates more equal amounts of reaction time for the baking powder, reducing the convexity by ensuring that the cake rises more evenly. To conduct the experiment, the following independent variables were tested while baking the cakes: cake strips, water baths, and cooking at a lower temperature for longer. The control had nothing altered from the conventional method of baking. The dependent variables measured and observed for this experiment were the height of the cake domes, the density of the cakes, the appearance of the cakes, and texture of the cakes. Both the qualitative and quantitative data found that cake strips are the most effective method for reducing the convexity on the top of cakes. The water bath was the second most effective but was significantly denser than any of the other methods. The results of this experiment can be easily replicated by other home bakers or anyone making cakes to reduce the amount of effort required to achieve level cakes.

Jordan Gross – Hydropower’s Effect on Greenhouse Gas Emissions
Collegiate School

This study investigates hydropower, a renewable energy source which utilizes the potential energy of falling water to spin turbines within a generator. The generator turns the kinetic energy of water into mechanical energy as the turbine’s magnets and wires interact with each other. This energy is transferred into electrical energy, which is sent to customers via power lines, and it is then used to power homes or buildings. Hydroelectric plants can either use the moving water of rivers to power the turbines, or they can use reservoirs, which coordinate the water’s release. However, criticism around hydropower arises due to the fact that it’s not completely green. Even though it is efficient over time, the initial construction and flooding of reservoirs release large amounts of greenhouse gasses (GHG) into the atmosphere, and the decomposition of organic materials also contribute to this carbon sum over a hydroplant’s lifespan. To address this criticism, the present study focuses on reservoir-powered hydroelectric plants. It tested two independent variables: reservoir depth and reservoir initial temperature. To do so, a 2L soda bottle was filled with different increments of water (250mL, 500mL and 750mL). Then, twelve grams of sodium bicarbonate were added to the bottle and dissolved using a magnetic stir bar. The intent of the experiment was to measure the effect of a reservoir’s initial temperature on gas release by measuring the container’s change in temperature, which was proportionate to gas production. However, a substantial flaw in the methodology was uncovered post-experiment and will be discussed at the end of this paper. A one-way analysis of variance (ANOVA) revealed that the change in initial temperature produced statistically significant results ($p < .001$), whereas the change in volume did not ($p = .142$). Therefore, the null hypothesis that deeper reservoirs will have a higher change in temperature was retained. The null hypothesis that reservoirs existing in warmer climates will result in smaller temperature changes was rejected. It is worth noting these outcomes could vary if the experiment

were performed on a greater scale. This data, and the highest corresponding temperature changes, show that in order to make hydroelectric power the most efficient in regard to carbon emissions from organic material, they should not be built in climates such as the Amazon, which are constantly exposed to higher temperatures.

Spencer Jacocks-The Effect of Different Behr Price Points on the Stain Resistance of the Paint
Clover Hill High School

The questions addressed by this experiment were how the price points of Behr paints corresponded with the stain resistance of the paint and how would altering price points of Behr paint affect stain resistance. The hypothesis of the experiment was the higher the price point of the paint the more effective it would be at resisting stains and the less it would vary from the control RGB values. 90 pieces of plasterboard were put into 6 groups with 15 plasterboards in each group. The groups were labeled untreated for \$68, untreated for \$84, untreated for \$100, \$68, \$84, and \$100. The plasterboard pieces were painted with white Behr paint valued at the price they were labeled with. After four weeks, each plasterboard that was not labeled untreated was systematically exposed to substances that cause stains (oil and dirt). After 10 minutes of exposure, they were wiped off. One hour after the plasterboard pieces had been wiped clean, the RGB values of each plasterboard piece were measured. For each price level, the RGB values of the treated plasterboards were compared to the RGB values of the untreated boards, and the percent similarity was measured. This data was used to come to a conclusion about how much the color changed for each paint and therefore how well each paint resisted stains. The mean was used as a measure of central tendency. The mean for the \$68 per 3.79 L Behr paint was 95.7 percent similarity, the mean for the \$84 per 3.79 L Behr paint was 94.7 percent similarity, and the mean for \$100 per 3.79 L Behr paint was 94.3 percent similarity. The null hypothesis of no significant difference was tested using a One-Way ANOVA test with a 0.05 level of significance and the null hypothesis was not rejected. The research hypothesis of the higher the price point of the paint was, the more effective it would be at resisting stains and the less it would vary from the untreated RGB values was not supported by the data because there was no clear trend expressed.

Edwin Kyle – A Novel High-throughput Screening Method to Identify Fluoride-ion-conducting Materials.
Academies of Loudoun

In a world that is becoming increasingly dependent on advanced forms of energy production and storage, batteries with higher capacity, higher discharge rates, and better stability must be developed. Currently, lithium-ion batteries (LIBs) are by far the most popular battery due to their relatively high capacity, high discharge rate, and long cycle life. However, LIBs, without further development, are expensive and poor performers in terms of automobile and aviation applications. Fluoride ion batteries (FIBs) shuttle fluoride ions between a cathode and anode instead of conventional

lithium ions and are a potential alternative to LIBs due to their high theoretical specific energy. However, few fluoride-ion-conducting materials are known to serve as suitable electrolytes for FIBs. To assist in the advancement of FIB technology, a high-throughput method for identification of potential fluoride-ion conductors was conducted using the open-source geometrical-topological software package, ToposPro, and quantum mechanical software package, CP2K. These software were used together to find crystal structures with high fluoride ion conductivity in the Crystallography Open Database.

Reagan Labert – Comparison and Analysis of the Compositions of Commercial Kombucha Products
Ocean Lakes High School

Kombucha is a fermented beverage made using a symbiotic culture of bacteria and yeast and has been the subject of recent studies concerning possible antioxidant and anti-inflammatory effects. However, the results have been overall inconclusive, with inconsistencies often attributed to differences in the composition of the tested kombucha. Therefore, in order to determine if commercial kombucha products exhibited statistically significant differences in composition across vendors, the conditioned media of pasteurized kombucha products were analyzed and compared to determine the distinctiveness of each sample's composition. Reverse-phase liquid chromatography-mass spectrometry was conducted to identify features present in the conditioned media, and principal component analysis was utilized to compare the concentration of each feature and determine the distinctiveness of the compositions across samples. Additionally, UV spectroscopy was used to generate each sample's absorption spectra, which was compared to determine whether the null hypothesis was rejected. Statistically significant differences in each sample's composition were revealed by principal component analysis, and these findings were supported by the existence of unique absorption spectra across samples, especially at wavelengths around 280 nm, where antioxidants are known to contribute to absorption. The rejection of the null hypothesis implies that incongruencies in kombucha's effects may be attributed to differences in the compositions of the tested kombucha. Furthermore, these results imply that kombucha vendors must be cautious when advertising antioxidant effects, since variations in the absorption spectra imply differing antioxidant concentrations. The components of the fermentation process that most heavily contribute to composition differences should be investigated by further studies.

Caitlin Paulk & Rowan Floyd – Creation of Alginate Beads to find Optimal Release of Catalase with Stimuli Responsive Capabilities
Governor's School @ Innovation Park

Alginate-based drug delivery systems can impact the control of the product when it is released and shows promise for effective and efficient drug delivery. Calcium chloride can be incorporated during the synthesis of the beads, creating

pH responsive properties. Throughout this study, alginate beads are altered utilizing drug to alginate ratio. During the creation of the beads, the amount of catalase to alginate will create 3 different ratios. As the pH of the calcium chloride coated alginate beads equalizes with a hydrogen peroxide solution, loaded catalase will release. Alterations are analyzed based on the rate of release of catalase in hydrogen peroxide. The catalase in the hydrogen peroxide bubbles when released, showing the effectiveness of each different ratio. Data was collected and analyzed based on time for the bead to float, and it was determined that as the catalase to alginate ratio approaches 1:1, the release time increased. Immediate future plans include conducting trials for more ratios and re-testing outlying data. Based on research found in pH-responsiveness, some foreseeable plans include conducting research into a set of varying concentrations of the calcium chloride solution and altering other external factors, such as heightened temperature, to test for the preservation of a sample in an alginate bead. In the future, the research of alginate bead drug release could be applied to treatment of various diseases, namely HIV. Plans include research and application of alginate bead drug delivery to Nef proteins in an E. Coli based model system of HIV.

Seth Richards & Aidan Mayhue -The Bioremediation of Perfluorooctanoic Acid by *Pseudomonas putida*
Roanoke Valley Governor's School

In recent years, pollution produced from manufacturing plants and household appliances has become increasingly prevalent worldwide. Per- and polyfluorinated substances (PFAS) are a group of long chain compounds utilized in manufacturing processes that cause human and environmental harms once becoming a pollutant. In this study, a form of PFAS, known as perfluorooctanoic acid (PFOA), was analyzed. The purpose of this study was to expose the bacteria *Pseudomonas putida* to concentrations of PFOA to examine the potential of *P. putida* to biodegrade the acid. It was hypothesized that if *P. putida* was introduced to mediums containing PFOA, then the bacteria strain would be capable of degrading at least half of the PFOA. In order to assess the bacteria's degradation potential, *P. putida* was exposed to PFOA concentrations of 0, 100, 200, 400, and 800 mg/L in LB medium broth for six days, and samples were then sent to Enthalpy Analytics to determine the remaining concentrations of PFOA. For bacterial tolerance tests, bacteria were exposed to well plates containing the mentioned concentrations of PFOA, and samples were evaluated using spectrophotometry for absorbance. Data from spectrophotometry found that the control supported bacterial growth significantly better than concentrations containing PFOA; however, bacteria in the 400 mg/L group grew significantly better than those in the 100 mg/L group. The LC/MS/MS technique found the bacteria was ineffective in the degradation of PFOA. Even though *P. putida* was not able to degrade the PFOA compounds, the bacteria displayed remarkable tolerance to PFOA conditions.

Asiya Shariff -The Effect of Plasticizer on pH of SODIS Purified Water
Mills E. Godwin High School

This experiment was conducted to determine the effect of plasticizers on pH of water and the effect of SODIS at mitigating the plasticizer effects. Plasticizer is the chemicals in plastic that increases malleability, and SODIS stands for solar water disinfection which is a method of purifying water. This experiment will display the effect of plastics in water and how some methods at purifying water might not be able to counter the pH change. Pure water was split up in four groups and varying amounts of plasticizer was added to produce different concentrations in each group. The control was 0% plasticizer concentration to measure the pH change against. The concentration of plasticizer increased and even after purifying the water through SODIS the pH decreased and the water was determined to be unsafe for human consumption. This could be because the acidity was too low for SODIS to be able to have a significant effect on the pH. At the concentration of 20%, the highest IV, the pH was the lowest. When adding Hydrogen Peroxide to water it brought the pH down to 4-5 and SODIS did not mitigate those effects. This experiment can have immense real-life applications since plastics in the ocean are a prevailing and current problem in the world as it reduces clean water for human consumption. The world's drinking water sources are polluted with plastic and countries that lack clean water use SODIS, however, this experiment proves SODIS is unreliable and research on maintaining water pH should be explored.

Sophia Sneed-The Effect of Cadmium-Based Paint, Exposed to Various Humidity Levels, on Change in Color of a Painting, Measured Using Image J Software
Clover Hill High School

Cadmium, though it can be toxic in large quantities, remains a key ingredient in paints. However, examples such as *The Scream* seem to indicate that cadmium paints are especially susceptible to degradation. The purpose of this experiment was to examine the relationship between relative humidity and the degradation of pigment in cadmium paint. The research hypothesis was that, as humidity increased, the pigmentation of exposed paint would decrease. The experiment was conducted by placing small squares of watercolor paper with cadmium yellow paint on them into a sauna and monitoring the relative humidity, according to the different levels of humidity observed, over a period of four days. Then, the squares were scanned and analyzed using ImageJ software. Average RGB values for each square painting were recorded before and after each group of thirty squares were exposed to humidity. Generally, the green values remained the same through exposure to increasing humidity, while red values decreased, and blue values increased with each group. This pointed to a whiter, faded appearance in the squares exposed to greater humidity. Overall, the null hypothesis was rejected after ANOVA tests were completed. Thus, the data supported the experimental hypothesis of the experiment.

Engineering A (HS EGR-A)

First Place

Paige Baldwin – Development and Testing of a New Method for measuring nearshore Turbidity-the 3D Coastal Comparator

Chesapeake Bay Governor's School

When testing turbidity in the field, the secchi disk is a common method of data collection. While secchi disks have been used since the 1850s, the data collected varies depending on the outside conditions, such as the lighting conditions or the weather. These devices also do not work well in fast moving water, high turbidity environments, or shallow nearshore environments. A proposed solution to these problems is a comparator, which eliminates the influence of outside light and can sample any body of water. For this study, a comparator was designed, built, and field tested in the lab using a spectrophotometer, testing the transmittance of samples. From these data, a visual scale was created correlating the measured transmittance percentages to photos of actual samples in the comparator. Based on the field data collected, the turbidity comparator was able to display a sufficient range of shades, from completely clear to opaque, indicating the limit at which turbidity is visually measurable. The majority of the ambient samples taken were within the 95% to 100% range of transmissivity. There were 12 samples above 95%, 4 samples within 90-95%, 1 within 85-90%, 1 within 80- 85%, and 2 within 65-70% transmissivity. With a precision of 5% transmissivity, the ambient samples collected were measurable using the comparator. The comparator device is useful for shore-based sampling and allows researchers and citizen scientists to get a general snapshot of turbidity in shallow coastal environments where secchi disks are not practical and secchi tubes are not as accurate.

Second Place

Karin Anderson -The Effect of Metallic Foil and Different Geometric Shapes on Light Reflection

Washington-Liberty High School

Stealth technology is an always evolving field that is constantly changing and growing. This specific experiment targeted just one area of the broad field stealth encompasses. The purpose of this experiment was to determine whether the specific heat capacity of a substance has an effect on the amount of light it reflects or absorbs. It was hypothesized that a metal with a higher heat capacity (aluminum), will reflect less light back to the origin because materials with bigger specific heat capacities absorb lighter than those with lower specific heat capacities. The independent variable was the type of metallic foil and the geometric shape of the foils; the dependent variable was the amount of light reflected back to the light source, measured in lumens. The experimental groups consisted of two V-

shapes 24 cm at the base and 2 W-shapes 12 cm at the bases, one of copper foil and one of aluminum foil. The control was a V-shape 24 cm at the base of paper and a W-shape 12 cm at the bases. The experiment was conducted by placing the control or experimental group under a cardboard box that had two holes cut out so that a phone and light source could be shone inside the box. This allowed light to reflect against the shape and be recorded by the lux meter located on the phone. The T-Tests between the Al W and V, Cu V and W, and Al W and Cu W were less than 0.05, whereas the T-Test between the Al V and the Cu V were not. These results conform to the research stating a V shape would reflect less than a W shape, but not the research pointing towards metals with higher heat capacities absorbing more light.

Third Place

Haley Cossman -The Effect of Different Forms of Plastic Waste on The Compressive Strength of Concrete
Central Virginia Governor's School

The purpose of this study was to determine the effect of plastic waste on the compressive strength of concrete. The study was conducted at a local engineering company during October of 2022. Four groups of concrete were constructed for this experiment: a control with no plastic, plastic beads, plastic filament, and plastic blast media. Each group had eight concrete samples and plastic was added in proportions of 10% by volume. After the concrete set, the compressive strengths were found. The average compressive strength of each concrete group was 3883.00 psi for the beads, 4484.13 psi for the filament, 4812.63 psi for the blast media, and 5178.75 psi for the control. A one-way ANOVA determined significance with a p-value of .0089 and an alpha value of .05. A post-hoc Tukey test determined where the significance was, with a Dmin value of 495.4. The plastic bead concrete had a significantly lower compressive strength than all other groups. The filament concrete had a significantly lower compressive strength than the control. There was no significant difference between the filament and the blast media or between the blast media and the control. This partially supported the research hypothesis, that plastic blast media would create the strongest plastic concrete, because the blast media concrete had the highest average compressive strength out of the plastic concretes, but it was not significantly stronger than the filament concrete. In conclusion, plastic blast media can be added to concrete without significantly decreasing the compressive strength.

Honorable Mention

Maxim Avrutin – Study of Diodes Made of Different Semiconductor Materials as Temperature Sensors
Mills E. Godwin High School

The objective of this project was to study the effectiveness of diodes made of different semiconductor materials as temperature sensors. Temperature sensors are important for numerous industrial applications. They are crucial for

monitoring temperatures to prevent overheating in integrated circuits. Silicon (Si) diodes are the most widely used semiconductor temperature sensors. However, Si diodes can only be employed at temperatures below 150–200 °C. At higher temperatures, the response of Si diodes becomes nonlinear because of changes in the electrical properties of the material, mostly due to breaking chemical bonds and the generation of new electrons and holes. The research hypothesis was that diodes made of semiconductors with stronger chemical bonds will provide a more linear response at high temperatures compared to the Si diode. In this experiment, two light-emitting diodes (LEDs) based on InGaN (blue) and GaAsP (red) semiconductors were tested in comparison with a Si diode. Both these materials have stronger bonds than those in Si. The voltage drop across three different semiconductor diodes was measured in the temperature range from 20 to 240 °C. The voltage across the Si diode decreased with increasing temperature at a rate of 2.4 mV/°C; however, it showed noticeable deviations from linearity at temperatures above 170 °C, in good agreement with literature data. The temperature dependences of the voltage drop across the InGaN and GaAsP based LEDs remained linear throughout the whole temperature range, so the research hypothesis was supported. For temperature sensor application, the red LED appeared to be a better option than the blue LED because of its higher sensitivity: the rate of the voltage change with temperature was higher for the red LED (1.7 mV/°C) than that for the blue LED (1.1 mV/°C).

Honorable Mention

Devon Davis – The Effect of Shielding Materials on Blocking Gamma Radiation
Central Virginia Governor’s School

The purpose of this research was to determine if there was a significant difference in gamma radiation shielding for selected materials and thicknesses. Three materials; lead, aluminum, and polyethylene, were used and each material had a sample at three different thicknesses, .062 in, .125 in, and .250 in. Each sample was tested eight times, for a total of 80 tests including a control group without any material shielding the radiation. Each individual test lasted five minutes, with data being collected every 30 seconds and then it was averaged. A Two- Way ANOVA determined significance, with the p-value of 3.36361E-51 for material, 1.51176E- 27 for thickness, and 2.04392E-29 for interaction effect, and an alpha value of .05. Then a Tukey test was used with a Dmin value of 9.433964 and a Qt value of 4.65, which determined that there was significance between the control and various thicknesses of lead and aluminum. The results determined that lead and aluminum have a significant effect on gamma radiation shielding over the control group while polyethylene did not. This partially supported the research hypothesis, which stated that if I used twice the thickness of aluminum and three times the thickness of polyethylene, then those materials would exceed the shielding capabilities of lead at the respective thickness. The results from this research can add to the growing body of information on effective methods of radiation shielding in order to protect the health and safety of people.

Honorable Mention

Pooshan Chaudhuri – Study of the movement of Superparamagnetic Iron Oxide coated *Cucumis sativus* cell clusters in presence of a Magnetic Field

Maggie L. Walker Governor's School

Three-dimensional cell clusters, also known as spheroids or organoids, are essential tools for understanding cell to cell interactions in tissues. Several methods for successfully isolating live cells from plant and animal tissues, building cell clusters and finally creating spheroids from these cell clusters are being investigated. The unique property of exhibiting magnetic susceptibility under the influence of a magnetic field makes Superparamagnetic Iron Oxide Nanoparticles (SPIONs) an effective tool for creating spheroids via contactless, guided movement of cell clusters. This study discusses a method for successfully coating cell clusters from *Cucumis sativus* with SPIONs and achieving guided movement of the cell clusters with the help of a magnet.

Aun Ali-GPUs vs. CPUs with Deep Neural Networks and Matrix Multiplication

Blacksburg High School

The rise of GPUs has created an environment where many think of GPUs as a panacea for computing scalability problems. However, GPUs may not always be able to deliver the promised performance. The results of this work will help establish whether the two studied classes of applications can truly benefit from GPUs, and thus provide for guiding future adoption of GPUs in that domain. The experiment defined two groups that would run two different tests, one group that would run benchmarks with CPUs only and one group that would run benchmarks with a CPU plus a GPU. These groups would run two different benchmarks both being measured in time to complete operation, these benchmarks running DNN and Matrix multiplication operations. I also established several hypotheses:

Null Hypothesis: The GPU will perform better on both the DNN and Matrix Multiplication tests

Alternative Hypothesis 1: The CPU will perform better on both tests than the GPU.

Alternative Hypothesis 2: The GPU will perform better on the DNN test and the CPU better on the Matrix Multiplication test.

Alternative Hypothesis 3: The GPU will perform better on the Matrix Multiplication test and the CPU better on the DNN test.

Results showed GPUs having time advantages in both tests. Suggesting that GPUs do in fact help performance in regard to time when it comes to DNN and Matrix Multiplication.

Emma Allen-Enhancing Sustainability in Parking Areas
Chesapeake Bay Governor's School

The urbanization of natural areas creates a significant problem of heat islands. The increase in the area of parking lots has greatly contributed to this phenomenon, especially over recent decades. This study examined the effectiveness of solar canopy structures in reducing asphalt temperature of parking lot surfaces under the cover. The angle of the cover of the solar canopies was also studied to determine the impact on temperature reduction. Eight solar canopies were built to test four different roof angles (0°, 5°, 10°, 15°); the ambient temperature of the asphalt directly exposed to sunlight was compared to the temperature of the covered asphalt under the solar canopy. The angled canopies were tested in the parking areas of three different locations in the Middle Peninsula and New Kent County over several months. The 15° angled solar canopy was the most effective model in all trials at all locations and statistically the best-performing canopy. Incorporating solar canopies to create covered parking areas will not only help mitigate the heat island effect of the parking lot but can also offer sustainable solar energy if outfitted with solar panels. Further, adding a water catchment system to the canopy roofs can harvest rainwater and reduce stormwater runoff. Temperature increase created by urban development degrades the quality of the environment, using solar canopies in these areas will not only lessen the negative effects of urbanization but also provide valuable resources of photovoltaic power and harvested rainwater.

Hanna Aklil and Lani Lin-Kissick – The Creation of Longer Lasting Concrete—An Analysis on the Infusion of Bacteria and Aggregates into Cement Concrete to Increase Durability at Varying Temperatures by Examining the Substances Following Water Absorption
Governor's School @ Innovation Park

Inducing bacteria into cement concrete can increase concrete durability and therefore its lifespan by preventing microcrack formation from the absorption of water. Bacteria have cell walls with the ability to produce CaCO_3 , which can increase the compressive strength of a substance and eventually, solidifying the structure as the cell dies. However, there is a lack of adequate data available to conclude which specific bacterium will increase the durability the most. Thus, the effects of four bacteria that each have unique properties (specifically *Bacillus subtilis*, *Sporosarcina ureae*, *Staphylococcus epidermidis*, and *Synechococcus sp. PCC 7002*) on cement concrete durability were assessed. A standard test to find the percentage of water absorption is modeled by the equation $(W_1 - W) / W \times 100$ where W is the initial mass and W_1 is the mass after absorbing water for five days. This water absorption test was used to infer that both *Sporosarcina ureae* and *Staphylococcus epidermidis* had the lowest average water absorption at a -0.17% decrease in mass (g) after a five-day period submerged in water. In addition, trials had absorbed water at three distinct temperatures to model different natural environments for cement concrete (specifically 04°C, 21°C, and 37°C). The concrete at 21°C tended to show a decrease in mass after water absorption, compared to the general increase in mass

at 04°C and 37°C. Overall, this study indicates the strain of bacteria imbedded into cement concrete and the temperature at which the concrete subsists have effects on the durability of cement concrete.

Micah Bierman -The Effect of Various Soundproofing Materials on Decibel Level
Washington-Liberty High School

This experiment was conducted to determine the best soundproofing material to be applied to minimize noise pollution, specifically in residential structures. It was hypothesized that if materials of different densities are tested for their soundproofing ability, then the carpeting will result in the most sound absorbed because of its natural fibers and density. If a material contains a low density, then it will be able to absorb more sound. Therefore, carpeting was hypothesized to be the best soundproofing material. Carpeting, acoustic 105tyrofoam, wood, and the control using no soundproofing were the independent variables tested. For each independent variable, the material was placed to cover the inside of a shoe box on all four sides, the top, and the bottom, and then a speaker was placed in the center of the fully lined box and the box was shut. A sound of 440 hz was played and the decibel level was measured, using a decibel meter, and recorded. The dependent variable was the decibel level. Each independent variable was tested a total of ten times and the means and standard deviation were calculated and graphed on a bar graph. The p value was calculated by running an ANOVA test, and the p value was 1.67E53. This p value meant that there were significant statistical differences between the groups and the null hypothesis, stating different soundproofing materials will have no effect on the decibel level, can be rejected. The results agreed with the theory that when sound waves travel through medians of low density, energy is removed from the wave and sound dampening effects occur. The data collected suggests that carpeting was the most effective soundproofing material because it resulted in the lowest mean decibel level, 50.21 dB. Conversely, the 105tyrofoam and wood resulted in similar recorded decibel levels of 61.35 and 65.75 respectively. These results provide insight into the best strategies for reducing noise pollution in residences.

Hayden Carwile – An Analytical Study of Water Hammer and the Effect of Different Valves
Central Virginia Governor’s School

The purpose of this study was to compare peak pressure induced by the water hammer effect in two different scenarios featuring a ball valve in one and a gate valve in the other. The research hypothesis stated that the peak pressure on the system with the gate valve would be lower than on the system with the ball valve. The study featured two ten-foot PVC pipes outfitted with different valves. A digital water pressure sensor outputting to an Arduino was used to measure peak pressure during the trials. The mean pressure for the ball valve group was 103.45 PSI and the mean pressure for the gate valve group was 100.70 PSI. The two groups of pressures were then compared using a two-tailed t-test assuming equal variance. The p-value of 3.34×10^{-9} was compared to an alpha value of .05, thus showing significance. The results showed that using a gate valve instead of a ball valve will reduce peak pressure induced by water hammer.

Mason Gallagher -The Effect of the Wind Turbine Blade Angle on Energy Production
Central Virginia Governor's School

The purpose of this study was to find the optimal blade angle of attack for energy production on wind turbines. The study was conducted in a local high school in December of 2022. Five blade angle groups were set and tested ranging from 5° to 20° . These were measured with a protractor and were placed on model wind turbine two meters from the wind source (fan). The mean energy produced in joules by 12.5° , the most efficient blade angle, was 3.778 joules. A one-way ANOVA determined significance, with a p-value of $1.8515E-23$ and an alpha level of .05. A Tukey test then determined between 1h groups the significance was held, with a Q_t value of 4.89 and a D_{min} of .37041. The most significant group from the Tukey test was 12.5° which had the most significant values compared to the other 4 groups. This did not support the original hypothesis that 45° would be the most efficient blade angle of attack. In conclusion, 12.5° blade angle of attack to the wind was the most efficient blade angle for energy production.

Engineering B (HS EGR-B)

First Place

Erika Milhorn – The Effect of Vertical Oscillation and Cycles per Minute on the Effective Detection of a 24 GHz Device

Central Virginia Governor's School

The purpose of this study was to determine if changes in ground contact time, vertical oscillation, and cadence (z-axis movement) had any effect on the detection ability of a 24 GHz radar device. A machine was built to mimic a runner's motion using these three variables. Data collection took place on a flat road with cones set up at one-meter intervals from 130 meters to 150 meters. The data was compared to two controls, one found during data collection and the other was the outermost range of the device. There were five testing groups with 25 trials in each. The groups were compared to the controls using two ANOVA statistical analysis tests. The p-value for the found control was .014 and the p-value for the given control was $2.7E-09$. Both of these were below the alpha of .05 establishing a statistically significant difference among groups. A post-hoc Tukey test was then performed demonstrating each group, when compared to the controls, had significance when compared to the Dmin values. The research hypothesis was supported because each of the five groups had 95% detection ability when exhibiting z-axis motion beyond 140 meters. This research demonstrates the plausibility of using a radar detection device for the safety of pedestrians along roadways.

Second Place

Layton Morris – What Car Windshield Angle Produces Maximum Image Sharpness?

Central Virginia Governor's School

The purpose of this study was to determine whether or not the angle of a windshield had an impact on the sharpness of an image when taken through said windshield and, if there was an impact, which angle provides the optimum sharpness. This study was conducted through the assistance of a local high school during December of 2022. A camera was placed on a table and focused on a target so that the target filled the field of view of the camera at that distance. Then, five groups of images were taken, one without a windshield and four others with the windshield placed at 40, 50, 60, and 70 degrees from the horizontal. All of the images were then run through the Imatest star sharpness test in order to quantify the sharpness values in terms of cycles per pixel. A single-factor ANOVA, with an alpha value of .05, was then run on the different groups and a p-value of 7.851×10^{-13} was returned. A Tukey test then determined with a Dmin of 9.508×10^{-3} that the differences lie everywhere except for between the 70- and 40-degree groups. The results

did not support the research hypothesis as the sharpness values increased as the angle approached 50 degrees rather than 70. This suggests that the optimum angle for image sharpness is close to, if not, 50 degrees. Therefore, if interior cameras are to be implemented in self-driving vehicles, they would work best on vehicles with a 50-degree angled windshield.

Third Place

Cooper Morford – Which Green Insulation is the Most Practical when Considering Cost, Thermal Efficiency, and Embodied Carbon?

Central Virginia Governor's School

The purpose of this research was to determine if cork, cellulose, sheep wool, or fiberglass was the most practical insulation material while considering their costs, embodied carbon values, and heat resistance properties as equal factors. Specifically, this research was conducted to test if cork, cellulose, or sheep wool could compare to fiberglass in the previously mentioned categories. Pre-existing data was used to determine the embodied carbon values and costs of each insulator. To test the thermal resistance properties of each material, a realistic wall segment was created. This wall segment was heated to 160 degrees Fahrenheit for 12 hours. A total of 10 trials were conducted for each material. Significance was found between each group tested with the use of a single factor ANOVA, which produced a p-value of 3.9×10^{-162} (alpha .05), and a post-hoc Tukey test. After analyzing this data along with the embodied carbon values and prices of each material, cellulose was found to be the most practical insulation, with cork, fiberglass, and wool following in that order. These results did not support the research hypothesis, which stated that cork would be the most practical insulation when considering cost, thermal efficiency, and embodied carbon as equal factors. This research could be greatly beneficial in terms of knowledge provided about the tested materials, as well as laying a groundwork for future research utilizing a similar methodology to test other insulating materials.

Honorable Mention

Micajah Mason -The Effect of Degradation on a Full Synthetic versus a Conventional Motor Lubricant's Tribological Performance

Central Virginia Governor's School

The purpose of this study was to determine which type of oil, synthetic or conventional, was most effective at maintaining its tribological performance when the oils experienced a simulated degradation process. The degradation of the oils was simulated by adding 3g of carbon particulates to 300ml of the oil. The oils were tested using a lubricity tester; a cast iron bearing was spun on an aluminum surface that was submerged in a vat of the oil type being tested. A wear mark was generated on the aluminum surface, the depth of this mark was measured to collect the data points.

An additional data point was collected by gathering a temperature reading at the end of the lubricity test. These data points were used to gather information and determine tribological performance. The two groups of contaminated oil were tested in this way. When the data was compared using a t-test statistical analysis, a p-value of 9.76E-09 was determined for the wear mark depth comparison. For the operating temperature comparison, a p-value of 6.47E-16 was found. When compared to an alpha value of 0.05, the synthetic oil was found to be the most effective at maintaining its tribological performance. This supports the research hypothesis, stating that the synthetic oil would be more effective than the conventional oil at maintaining its tribological performance when the contamination occurred.

Honorable Mention

Kedar Kambhampaty- Effect of Algorithm Choice on Automated Face-Detection in Images of Occluded Faces
Washington-Liberty High School

Occlusions of the face in captured images can prove a challenge for facial detection and recognition algorithms, degrading performance and causing both false negative and false positive results. This experiment explored the effect of different facial detection algorithms on detection accuracy against the Specs of Faces (SoF) dataset, which focuses on occluded faces. The algorithms tested were Haar Cascades from OpenCV, the deep neural network (DNN) module from OpenCV with an externally trained model for occluded faces, MTCNN (Multi-Task Cascaded Convolutional Networks), and the face detection model from Google's MediaPipe library. It was hypothesized that MTCNN would perform the best, as it implemented a cascaded technique with deep convolutional neural networks, boosting successful networks with a more efficient and accurate cascading system. Each algorithm was implemented in Python and tested on a collection of 1,833 images selected from the SoF dataset. The total count of images, and the number and percentage of positive face detections were tabulated for each algorithm.

A chi-squared (χ^2) statistic was estimated based on the tabulated data, to test the null hypothesis that the accuracy of face detection is the same for all four algorithms tested. The estimate of 1,383.939 is well above the critical value of 7.815 for a χ^2 distribution with 3 degrees of freedom and a significance level, α , of 0.05, rejecting the null hypothesis. The externally trained DNN algorithm had the highest rate of positive detections, at 99.7% while MTCNN had a 86.3% rate for positive face detection, rejecting the study hypothesis that MTCNN would be the most accurate of the four algorithms.

Honorable Mention

Christopher Hedrick -The Effect of Ratio of Ash to Cement, When Used to Make Cement Brick, on the Compressive Strength of the Brick
Clover Hill High School

The purpose of this experiment was to determine the effect of ash on the compressive strength of cement brick. Knowing the effect of incorporating hazardous waste into construction materials, expenses along with the amount of waste going into hazardous landfills could be cut down while still maintaining the compressive strength of the cement up to standards. The hypothesis was that the more ash there was in the brick mixture, the greater the compressive strength of the brick would be. To measure the compressive strength of each brick, the bricks were placed into a pipe screw clamp. A digital spring scale was then used to calculate the Newtons required to make the brick crumble, calculated using the Torque-forward drive formula. The four levels of the independent variable were the control trials, the 50 grams of ash trials, the 100 grams of ash trials, and the 150 grams of ash trials, with each level having 1000 grams of cement. Each mixture was mixed with water, dried, and baked before being put into the pipe screw clamp. The compressive strengths were recorded in a data table, and this process was repeated until each level had 30 complete trials. The control trials (no ash) produced a mean compressive strength of 1191.357 N. The 50 grams of ash trials generated an average compressive strength of 270.330 N. The 100 grams of ash trials generated a mean compressive strength of 64.544 N. The 150 grams of ash trials produced a compressive strength of 33.668 N on average. The null hypothesis of no significant difference was tested using an ANOVA test, and the null hypothesis was rejected. Due to the decrease in compressive strength with the further addition of ash, the research hypothesis was rejected.

Nicholas Gregoriou – Brass Instrument Mouthpiece Design and Lip Reed Acoustics
Ocean Lakes High School

The field of acoustics, although associated with music and subjectivity, is rooted in physics. Every musical instrument works by manipulating a vibrating body to produce a desired sound. For brass instruments, this means vibrating the player's lips in a mouthpiece and pushing that air through the rest of the instrument. This research project explores the effect a trombone mouthpiece's material has on the instrument's sound, as well as the processes for accurately quantifying the musical concept of timbre. It was hypothesized that the material composition of a trombone's mouthpiece does not have an effect on its timbre. To test this, multiple wooden mouthpieces were constructed, and their acoustic properties were measured through the Audacity computer software. The hypothesis was disproven, with it being concluded that mouthpieces made from denser, harder woods have a more similar timbre to a control mouthpiece.

Krish Gupta – Aquatic Plants based Water Filtration
Washington-Liberty High School

Declining water quality is a major global issue affecting delicate ecosystem and worsening human suffering across the

world. Phytoremediation is a low cost and effective method which has been shown to remove various contaminants at point source or in polluted water bodies. The novel technique utilizes certain aquatic plants to specifically remove or reduce common water toxins including various heavy metals and sulfates. It was hypothesized that by utilizing these properties it will be possible to improve the quality of water from a local river source. Additionally, the experiment also aimed to compare the quality of water filtration between 3 different well known aquatic plants namely, Water Hyacinth, Water Cabbage, and Water Fern, each of which have proven phytoremediation properties. The variables tested were common water quality indicators such as pH, Total Hardness, Total Alkalinity, Copper, Lead, Sulfate, Nitrate, Total Dissolved Solids (TDS), measured in particles per million (ppm). The results proved, water treated with these aquatic plants versus untreated water had improved pH and reduction of heavy metals concentration and this difference was statistically significant. Additionally, between the aquatic plants sub-groups, Water Hyacinth was more effective than Water Cabbage or Water Fern in improving the quality of water. In conclusion, the results indicate that phytoremediation is a viable and simple technique which can be used to purify contaminated water in a cost-effective manner.

Emma Hensch -The Effect of the Catholyte on the Power Produced by a Microbial Fuel Cell
Washington-Liberty High School

This experiment investigated the effect of the salinity of the catholyte on the power output of a microbial fuel cell (MFC). MFCs are a sustainable power source and run on organic waste. Environmentally integrated MFCs may function differently depending on their location. Salinity is increasingly a concern for waterways in the DC region, so stream water (the control), tap water with 6g and 12g of salt, and tap water with 6g of sodium-containing detergent were tested as catholyte solutions. Conductivity was used as an indirect measurement of salinity, and stream water was the control. The dependent variable was the power produced by the MFCs, which was calculated as the product of their voltage and current. It was hypothesized that if the conductivity of the catholyte was higher, then the power produced would be greater, because the solution would be a stronger electrolyte, which would allow for more movement of charged particles and make the voltage of the circuit higher. The group with the highest power output was the detergent group, and the lowest was the 12g salt group. An ANOVA test returned a p-value of 0.18, meaning there was no statistically significant difference between the means of all groups. Since all of the trials had low voltage and current measurements that were difficult for the multimeter to read, the data were not very precise. There are many possible reasons for the overall variance, including inconsistent salt bridges and water-to-mud ratios in the cells.

Lincoln Hunley -The Effect of Interior Padding Material on the Impact Absorption of American Football Helmets
Central Virginia Governor's School

The purpose of this study was to determine the most effective form of interior padding in football helmets from two options, to reduce the maximum force sustained by an athlete. This study was conducted at a local high school in November of 2022. In order to test the two types of padding, the helmets were individually tied by a string at the top of a frame which allowed for the helmets to be swung into a wall for twenty different trials. The helmets had a head form with an accelerometer attached to the forehead within it, allowing for the acceleration of each impact to be measured. This acceleration value was then multiplied by the weight of each helmet, which yielded the force value for each impact. A two-factor t-test yielded a p-value of .107, which when compared to the alpha-value of .05 determined that there was not statistical significance in the effectiveness of the two types of padding. This data did not support the research hypothesis, which was that the air bladder type of padding would sustain less of the force of an impact. In conclusion, there was no significant difference in the performance of the two different types of interior padding in this study.

Catherine Meyer -The Effect of Electrical Resistance on the Energy Output from a Hydropower Turbine
Central Virginia Governor's School

The purpose of this study was to determine the optimal resistance to effectively regulate the flow of energy in hydropower plants. This study was conducted in an analytical lab at a local high school during November and December of 2022. The hydropower model used was an Eisco Water Turbine with Dynamo Mode, which a RV Water Regulator was also attached to ensure that the water pressure would be at 20 psi throughout the experiment. Resistance levels ranging from 10 Ω to 200 Ω were applied using the Vernier Variable Load, and the power output was collected on Vernier Graphical Analysis using the Vernier Go Direct Energy Sensor. A one-factor ANOVA test with the alpha value of .05 was used to analyze these data and determine if there was significance between the group without resistance and the groups with resistance. The determined p-value from the one-factor ANOVA test was 1.382×10^{-107} , which when compared to the alpha value determines that there is significance. A Post-Hoc Tukey Test was run to determine the location of significance. The research hypothesis—if electrical resistance is applied to an optimal water pressure input, then the power output will directly increase as the amount of resistance is increased—was not supported. Rather, the study suggested that as the applied electrical resistance increases, the power output will decrease. This can be helpful in making hydropower plants more efficient as resistance could ensure that the flow of water will be homogenous and prevent overproduction of electricity.

Dhruv Narayanan Prakash-Exploring the Perception of Blockchain Technology through Sentiment Analysis of Media Content
Deep Run High School

Being a very recent technology, blockchain and applications based on it have garnered quite a bit of attention. To

further explain, a blockchain is a digital network of decentralized and distributed data (ledger), which users share the ownership and management of. It offers many benefits, such as immutability of transactions, traceability, and transparency. However, as with most new technologies, it has come under heavy skepticism and criticism. The aim of this paper is to analyze the perception of blockchain technology through the sentiment analysis of social media and news content. The study also looked at the correlation between blockchain and its various applications. It has been found that the blockchain is heavily correlated with NFTs, cryptocurrencies, and games. This evidence indicates a general need for the knowledge of blockchain, its underlying ledger technology, and its multiple applications. In addition, the terms with the highest correlation with blockchain were found to have negative sentiments attached to them. However, overall sentiment toward blockchain adoption was still positive

Engineering C (HS EGR-C)

First Place

Samvrit Rao – BOREAS: Innovating Respiratory Care Through Telemedicine
Thomas Jefferson High School for Science and Technology

Telemedicine has been heralded as the innovation that can help bridge the health care gap across the globe. The COVID-19 pandemic has facilitated the adoption of telemedicine as the primary mode of care for medical consultations in the United States, particularly for the diagnosis of respiratory diseases. However, a significant limitation of telemedicine is its inability to transmit breath sounds, a crucial clinical data metric essential for the diagnosis of respiratory diseases. As a patient suffering from chronic respiratory disease, I was inspired to create BOREAS, a unified hardware-software solution to capture and transmit breath sounds via telemedicine. The BOREAS platform consists of a lapel microphone capture device and an app that utilizes a Javascript-based framework. It was designed, built, and assessed using multiple breath sound libraries. The results of the waveform analysis of the transmitted breath sounds via the BOREAS platform indicated a high level of accuracy. Furthermore, the integration of machine learning utilizing the Littmann Library enabled the recognition of breath sound patterns, validating the efficacy of the BOREAS platform and facilitating accurate diagnosis of respiratory diseases. Also, when breath sounds were transmitted to expert physicians blinded, they identified the sounds with a high degree of confidence. In summary, BOREAS can accurately capture and transmit breath sounds, a diagnostic parameter that is lacking in existing telemedicine solutions. This innovation holds the potential to impact global healthcare by reducing the morbidity and mortality associated with respiratory diseases, helping millions of patients worldwide.

Second Place

Brian Zhou – Using Novel Constraint-Guided Models to Predict Kinematic Gait Outcomes on an Underwater Flapping Fin Propulsion System
Thomas Jefferson High School for Science and Technology

Unmanned underwater vehicles (UUVs) require greater maneuverability and propulsive efficiency to meet the design requirements for an expanding envelope of operations such as researching vast unexplored depths or military surveillance in ports and vessel tracking. A potential solution lies in biomimicry, a field that studies the biological designs of marine animals that swim with high propulsive efficiency and maneuverability and offers tremendous potential for improving the efficiency of UUV designs. Previous studies have explored replicating fins in robotic design and optimized fin structure, thrust generation, and material choices, but there are no studies on optimizing power consumption and,

consequently, efficiency. To resolve this gap in the literature, I develop a non-dimensional figure of merit (FOM) that is able to evaluate the efficiency of different fin designs and kinematics and allow for comparison with other bio-inspired platforms. I create and train practical computational models that are constrained by computational power and time using collected experimental data to run on a control system and use these models to predict thrust and power under different fin states; generated efficiency profiles have a 0.09% average error. I use the FOM to analyze optimal gaits and compare the performance between different fin materials, recommending the PDMS 1:10 material and specific gaits for further study. These comparisons provide insight into how materials and movements affect our thrust generation and propulsive efficiency, allowing me to develop a novel inverse gait-selector model which makes real-time adjustments and optimal movements, previously unachievable for small underwater autonomous systems.

Third Place

Joyce Xu – A Microfluidic Paper-based Bioreceptor Utilizing Colorimetric Properties for Detection of D-Glucopyranose in Epidermal Sweat
Mills E. Godwin High School

D-Glucopyranose (glucose) is a commonly surveyed chemical due to its importance in diabetic patients. The constant monitoring of glucose can be tiring and invasive methods through blood can be stress-inducing, costly, and time-consuming. Developing a non-invasive method of glucose detection through epidermal sweat creates a convenient and efficient system for rapid monitoring. In this work, multiple designs composed of flexible Polydimethylsiloxane (PDMS) silicone with channels were fabricated to transport sweat onto a filter paper disc pre-treated with appropriate detection reagents. PDMS is a variant of silicone often used in microfluidic devices for its flexibility and stretchability in stressed conditions. PDMS was cured in molds with embedded wires to create various transport channels. The wires were faintly lubricated to facilitate easier removal. A colorimetric reaction was mainly derived from the production of hydrogen peroxide and iodine by glucose oxidase and horseradish peroxidase, respectively. Filter paper discs were drop cast with the chemical cocktail and inserted between the base PDMS layer with transport channels and a thin layer of PDMS with small ports created for direct access of a sweat surrogate (e.g., D-Glucopyranose). Another microfluidic design utilized salt crystals as a sacrificial template to create a porous PDMS membrane for the uptake of sweat surrogate. The indicated colorimetric alterations of the filter paper upon exposure to the glucose solution demonstrated the effective transport of liquid through the channels and porous membranes of PDMS. This method of non-invasive glucose detection potentially enables immediate and conventional monitoring of patients with diabetic conditions.

Honorable Mention

Tess Vithoukas -The Effect of Different Filtration Methods on the Amount of Microplastics in Drinking Water
John Randolph Tucker High School

Humans have accelerated the widespread use of plastic, and now small fragments called microplastics are ending up in humans' food and drinking water from pollution, plastic degradation, and humans' actions. Research has suggested that ingesting microplastics may cause many negative effects. Different methods have been tested to separate and quantify the amount of microplastics, but none have been widely accepted. The purpose of this experiment was to determine which filtration method removed the most microplastics from drinking water. Four different filtration methods were selected as the independent variable: the Henrico County Water Treatment Facility (HCWTF) combined filter, a glass microfiber filter, a custom magnetic filtration method, and a multi-step filter, plus a control of post-disinfected, pre-filtered drinking water. Based on research, the hypothesis was if a magnetic filter is used, then the most amount of microplastics will be removed. The control, a sample of pre-filtered water, was divided and filtered to see which method would remove the most microplastics as measured by total organic carbon (TOC), the dependent variable. Post-filtered water from each filter was tested for TOC. Four trials were conducted. Data showed that the magnetic filter had the highest TOC levels, and the ANOVA test confirmed that the means were statistically different than the control since the f-value exceeded the f-critical value, and the p-value was less than 0.05. The Tukey's HSD test also confirmed that the mean TOC from the magnetic filter was statistically different than that of the control. Thus, the hypothesis was not supported.

Honorable Mention

Georgianna Wynnyk -The Effect of Different Eco-Friendly Oil Treatments on the Strength of Pine Wood
Central Virginia Governor's School

The purpose of this experiment was to determine whether or not certain oil-based wood treatments would significantly affect the amount of force that pine wood could support until fracture. The hypothesis was that Tung Oil would strengthen the wood most effectively in comparison to the other oils. Force was applied to five different groups of wood: Hemp oil, Citrus Hemp oil, Tung Oil, Linseed oil, and untreated Pine wood. Each group consisted of twelve samples, totaling sixty samples. The force was calculated through Vernier Materials Tester, and the means of the samples were collected and calculated using an ANOVA One-Way Statistical test. A p-value of .036 was determined, which was less than the alpha of .05, indicating a significant difference between groups. A post-hoc Tukey Test determined where the significance was between the groups; my Qt value was 4.04 and my D-min value was 42.10. The Tukey Test determined that the significance was between the untreated group and all of the other groups – the untreated group broke under much more force than the others. As a result of the data analysis, the null hypothesis was rejected and the original hypothesis was not supported as none of the oils increased the strength of the wood when tested with the materials tester. The results suggest that although the oils are designed to improve the aesthetics and may prevent future damage to the wood, they do not increase the original strength of the wood according to the data analysis of this research.

Honorable Mention

Sriya Sridhar – Utilizing Flow Cytometry to Evaluate the Sanitization of a 96 Well Plate by the Opentrons Liquid Handling Robot

Blacksburg High School

Each year, biomolecular laboratories generate a combined total of nearly 5.5 million tons of plastic waste. A major source of this single-use plastic waste can be attributed to 96 well plates, which cannot be recycled since they are used to handle hazardous biowastes. The objective of this study is to use an Opentrons Liquid Handling Robot to thoroughly sanitize a 96 well plate, and to determine effective cleaning methods to ensure the least residue. This research consists of two phases: the programming of the Opentrons Liquid Handling Robot to perform a variety of cleaning cycles, followed by flow cytometry to validate the sanitization by measuring *Saccharomyces cerevisiae* yeast cell count remaining in the wells. A Python protocol was programmed for the Opentrons robot to iterate through columns and rows of the 96 well plate and perform a different cleaning cycle for each of the rows. Wells were sanitized with different cleaning protocols that consisted of varied combinations of a simple rinse using deionized water, bleach, hydrogen peroxide, and either heated or unheated deionized water. The quality of cleaning for each method was tested with flow cytometry, which measured for the amount of forward and side light scatter detected, as well as the fluorescent protein mScarlet. It was established that sanitizing wells containing *S. cerevisiae* cells with bleach, hydrogen peroxide, and deionized water removed nearly all cells and bleach residue. This was confirmed by flow cytometry, which detected a nearly identical absence of cell or cleaning solution residue counts between unused and sanitized wells.

Robert Race – Effects of Thermodynamic Processes on Aerospace Materials and their Properties

Ocean Lakes High School

Aerospace engineers must evaluate materials and select ones that have ideal properties for specific applications in construction of spacecraft, many materials being metals. To make metals stronger and longer-lasting for their purposes, they are often heat-treated. The goal of this research was to determine whether heavy metals and alloys, titanium-6Al-4V and tantalum, would increase hardness after extended periods of heat treatment. This included analysis and exploration of the effects of extended heat treatment on the diffusion bond of an already diffusion-bonded piece containing titanium-6Al-4V and tantalum. It was hypothesized that if the samples were heated for longer, the samples' overall hardness would increase. To test this, multiple samples were heat treated and subjected to the Vickers hardness test. Scanning electron microscopy and energy dispersive spectroscopy aided in exploring the diffusion bonds' changes. Samples came from a plate of titanium-6Al-4V and tantalum that had already been diffusion-bonded at 890°C for two hours. Heat treatment was done at 860°C for 4 hours and 16 hours, including a sample that was not treated. Results of the experiment showed that the average Vickers hardness values were 223.66, 242.45, and 233.65 for the zero-hour, 4-hour, and 16-hour treatments, respectively. Analysis of results using the means was performed. A one-

way ANOVA test gave a P-value of 0.88, failing to reject the null hypothesis. Despite patterns explored from the results, it was concluded that there was no significant difference between the mean hardness values when affected by varying duration of heat treatment.

Grant Shindler -The Effect of Propeller Design on Amount of Net Force
Clover Hill High School

The question that was addressed in this experiment was which design of aircraft propellers would produce the most net force. The purpose of this experiment was to determine the effect of propeller design on the amount of net force that is created. Determining the best design for aircraft propellers is very useful because every single airplane uses them, and the ways of modern human life cannot go without aircraft. The research hypothesis was that a propeller diameter of 18 centimeters would produce the most net force, and a propeller with 5 blades would produce the most net force. To find how much net force a certain propeller design creates, a motor was put onto a scale and the propeller lifted the scale to get a reading of force. The propellers were designed using 3D design software and were printed out using a 3D printer. The designs varied in propeller diameter, and in the number of propellers. The control had a diameter (12.5 cm) and number of blades (3) was modified to where the diameter or the blades, not both, changed. With 3 levels the independent variables had 10 cm, 15 cm, or 18 cm in diameter, or had 2, 4, or 5 blades. Each propeller, 6 independent variables and 1 control, was tested for 1 minute each where every 2 seconds the output from the scale was recorded. To run the trials, the propeller was put onto the motor and the motor was turned on where it ran at constant output therefore each propeller received the same amount of power from the motor. A table was created where all 30 trials for each of the propellers were recorded. After the data was collected, the data showed that the most mean force was 4.573 g from the 12.5 cm and 2 bladed propeller. The lowest mean was 1.939 g from the 10 cm and 3 bladed propellers. In addition, an ANOVA test was run and determined that the data was significant. The null hypothesis was rejected for this experiment. The research hypothesis was not supported as the data shows the opposite of what was thought in regard to blade count, and for what was thought in regard to propeller diameter.

Benjamin Southall -The Effect of Humidity on Solar Panel Efficiency
Central Virginia Governor's School

This study was conducted with the purpose of determining the effect of humidity on the efficiency of photovoltaic solar panel energy production. This study was conducted in a lab at a local high school during November and December of 2022. LabQuest energy reading devices were connected to multiple solar panels to measure their energy production in voltage. The solar panels were placed in an incubator with a light source, to supply energy to the panels, and a humidifier, to vary humidity levels between trials. Four groups were used in this study each representing a different

percentage of humidity: 35%, 65%, 80%, and 95%. The mean voltages for each of these groups were 2.097, 2.075, 2.034, and 2.085 volts, respectively. The average voltages for each trial were analyzed in a single factor ANOVA test to evaluate significance between the four groups with differing humidity percentages. The p-value from this test, .0503, was found to be higher than the 95% confidence interval alpha value, .05, which suggests no significance between the groups. Because of this, the null hypothesis was retained. The data did not support the research hypothesis which stated that humidity and solar panel energy production experienced a significant, inverse relationship. In conclusion, humidity is not suggested to have a significant effect on solar panel efficiency.

Abigail Spickard – Effect of Heat Dissipation Techniques on Peltier Device Based Atmospheric Water Generator Performance
Central Virginia Governor’s School

The purpose of this study was to determine which heat dissipation technique, being the use of an inactive heat sink or an active heat sink, would produce the most water from an atmospheric water generator (AWG). This study was conducted in the lab of a local high school in December of 2022. The fan-based AWG first operated in a controlled humidity and temperature chamber and produced 2.03 ml of water at a relative humidity rate of 67.7% and a temperature of 63.84°F on average. The second AWG group, which relied on a series of two finned heatsinks to produce water, generated 0 ml of water at a humidity rate of 85.2% and a temperature of 62.5°F on average, while operating in the same chamber as group 1. A two-sample t test produced a value of .00037 for the p-value, which when compared to an alpha of .05, shows statistically significant results. The research hypothesis, which stated that if the fan based active heat sink dissipation technique was used then the system performance of the AWG would produce more water than if the inactive heatsink based dissipation technique was used, was supported. In conclusion, the use of an active heatsink, being the combination of a fan and a finned heatsink, generated the most water when compared to the inactive heat sink dissipation method.

Sam Yarbrough -The Effect of Blade Angle on Water Turbine Energy Production
Central Virginia Governor’s School

The purpose of this experiment was to determine whether the angle of the blade on a tidal turbine had significant effects on energy production. The hypothesis was that an angle of 40 degrees would produce the greatest amount of energy. Four different blade angles were tested; 0, 20, 40, and 60 degrees, and each angle was subjected to 10 trials. The energy output for each design was averaged and compared to the other designs. A one-way ANOVA determined the significance, with a p-value of 1.779E-13 and an alpha of .05. A post-hoc Tukey test then determined which groups the significance lay, with a Q_t of 3.85 and a D_{min} value of .0482. The test identified that the significance was found to

be between the 0, 20, and 40-degree angles, with the 20-degree angle having the greatest energy production. This did not support the original hypothesis, that the 40-degree angle would produce the greatest amount of energy. In conclusion, the angle of the blade did have a significant impact on the energy production of a tidal turbine. These concluded results help improve water turbine designs, which increases energy production, therefore decreasing the dependency on fossil fuels.

Environmental & Earth Science A (HS ENV-A)

First Place

Alex Bartl - Effect of Modifying Sorbents on Oil Sorption

Washington-Liberty High School

Oil spills are a great environmental concern because of the health impacts to marine life. This experiment was designed to test which of four natural organic sorbents were the most effective at absorbing oil. The four sorbents tested were peat moss, rice husks, ground corn cobs, and straw. It was hypothesized that peat moss would soak up the most oil in 45 seconds because it absorbs 10 times its weight in oil. To simulate an ocean environment, 40 grams of salt was added to 1,000 mL of water, and then 75 mL of oil was added to simulate the oil spill. Five grams of sorbent were used to absorb the oil, and after the time expired, a defatting cup was used to separate the remaining oil and water. The oil was then weighed in the defatting cup, and the weight of the oil was recorded as the result of the trial.

Peat moss was the most effective sorbent, absorbing 58% of oil in the bowl. Straw absorbed the second most amount of oil, absorbing 46% of oil in the bowl. Rice husks absorbed 37% of oil in the bowl, while ground corn cobs were the least effective, absorbing only 18% of oil originally in the bowl. ANOVA and T-tests were conducted, and all seven tests found that the data collected was significant, meaning that the p-value was less than 0.05. It was concluded both rice husks and ground corn cob were ineffective at removing oil from an oil slick as their removal rate was below 45%. However, peat moss and straw could be successful in an actual oil spill because their removal rates are greater than 45%.

Second Place

Drew Barnett -The Effects of Pollution Source on Microplastic Concentration in the James River Watershed

Central Virginia Governor's School

The purpose of this research was to determine if there is any significant difference of microplastic pollution between different pollution sources. To explore this, soil samples were collected along the James River in four different locations that would measure pollution from different sources: industrial, urban, suburban, and a control spot with no direct pollution. Then, the microplastics were separated from the soil using a high-salinity solution and counted under a microscope. After the data was collected, an ANOVA ($\alpha = .05$) determined that there was indeed significance ($p = 4.59 \times 10^{-8}$), and a post-hoc Tukey test discovered that industrial and urban sites had significance when compared to the suburban and control site. The research hypothesis, that the urban site would contain the most microplastics, could

not be supported as the industrial site had more, despite this difference being insignificant. In summary, microplastic concentration was significantly impacted from industrial and urban pollution.

Third Place

Anna Dodge -The effect of *Lemna minor* vs. *Eichhornia crassipes* on the remediation of crude oil from water.
Central Virginia Governor's School

The purpose of this research project was to look at aquatic oil spills and determine if there are less harmful ways to remediate the oil out of the water through the use of aquatic plants, *Eichhornia crassipes* and *Lemna minor*. The research hypothesis stated if aquatic plants, *Lemna minor* and *Eichhornia crassipes* are exposed to a 10 mL concentration of motor oil, then *Lemna minor* will filter out and absorb the most amount of that oil. In this study, *E. crassipes* and *L. minor* were placed into 200 mL cups of spring water with 10 mL of motor oil, which was used as a model for crude oil. These plants were allowed to sit for a week with light from 7am until 7pm. After one week, the plants were removed, and the oil was separated from the water using a pipette. The results for this study were inconclusive due to some experimental issues including the number of control groups, methods for plant removal, and methods for oil measuring. Therefore, neither the research hypothesis or null hypothesis can be supported by the data. Although this study did not produce accurate data, the mistakes can be used as an example and can help create future research experiments to help further learn about the effectiveness of bioremediation of aquatic plants.

Honorable Mention

Roayba Adhi -The Effect of Food-Grade Flocculants on the Aggregation of Simulated Microplastics in Polystyrene-Contaminated Water
Washington-Liberty High School

Microplastics are miniscule particles of plastic that have seeped into the world's supply of drinking water, all while carrying contaminants that are potentially dangerous for humans. Using the process of coagulation-flocculation for microplastic filtration, wastewater treatment plants (WWTPs) utilize environmentally damaging synthetic flocculants that biodegrade slowly and generate toxic byproducts. Thus, the purpose of this investigation was to determine which food-grade flocculant is the most effective natural alternative to the flocculants used today. The flocculants experimented on were okra, aloe vera, and prickly pear cactus, while the control was no flocculants. It was hypothesized that okra would be the most effective in aggregating the simulated microplastics in polystyrene-contaminated water due to its polysaccharide-rich mucilage that works as a binding agent to hold particles together. This experiment was conducted by adding food-grade flocculants to water containing simulated polystyrene-microplastics and calculating the average microplastic aggregation after 24 hours for each of the flocculants. The

results indicated that okra allowed for the greatest microplastic aggregation, as the mean mass of simulated microplastics remaining post-filtration was 3.4 grams. In contrast, the control allowed for the least microplastic aggregation, as the mean mass of microplastics remaining post-filtration was 4.7 grams. As such, the data gathered suggest that the food-grade flocculants used are potential natural alternatives for effective wastewater treatment and prompt the need for testing combinations of such flocculants for optimal aggregation results.

Honorable Mention

Jacob Cantrell -The Effect of Lead Acetate on *D. magna* Population Stability
Central Virginia Governor's School

The purpose of this study was to evaluate how the introduction of lead acetate(ii) into an aquatic environment affected the population sustainability and heart rate of *Daphnia magna* living in said environment. This study's three groups, the 250 µg/mL group, the 500 µg/mL group, and the control group, each contained three individual populations of 10-20 *D. magna* that were exposed to the prescribed amount of lead acetate(ii), which was dissolved into the water of the *Daphnia*'s containers. Researchers spent three weeks recording heart rate once a week and mortality twice a week. Through the use of two analyses of variance, with an Alpha value of .05, the average mortality and heart rate of each research group were analyzed and compared. The pvalue of heart rate was .83, which indicated there was no significant difference between the average heart rate of the research groups. However, a p-value of .00 for the mortality indicated a significant difference. A post-hoc test showed this difference was observed in the mortality between the control group and the 250 µg/mL group. The 500 µg/mL group was not significantly different from the other two groups. The hypotheses that higher lead acetate(ii) concentrations in the water leads to a higher average heart rate and that higher lead acetate(ii) concentrations in the water leads to higher average mortality were not supported by the evidence. It is likely that a confounding variable was at play and that future research is necessary to draw more conclusions.

Honorable Mention

Radhika Bharambe -The Effect of Copper Sulfate on Invertase Activity
Mills E. Godwin High School

This experiment was performed with the purpose to see if copper sulfate affected the invertase activity present within living organisms in the environment. Heavy metals, particularly copper sulfate, are used in many industries and as a result, often end up in soil ecosystems through heavy metal wastewater. By polluting the soil, excessive metal accumulation can result in a harmful effect on the plants in the soil and organisms in the environment. To test this, different amounts of copper sulfate along with distilled water, sucrose, and invertase were added to a test tube and after a determined amount of time, tested for glucose which would indicate sucrose hydrolysis through invertase

activity. The control of this experiment was 0 mL of copper sulfate, and the other independent variable levels were 3 mL and 6 mL. The research hypothesis created before experimentation was that if invertase is exposed to 6 mL of copper sulfate, then the amount of glucose formed through sucrose hydrolysis will be the lowest. The results showed that 6 mL of copper sulfate resulted in the least enzyme activity, whereas 0 mL of copper sulfate resulted in the most enzyme activity. All t-tests indicated that copper sulfate impacted enzyme activity, and the data sets were due to this, not chance or error. From this experiment, it is believed that copper sulfate can affect the invertase because of the metal's damage to the protein structure. Further research recommendations include looking into other enzymes and other heavy metals.

Anna Alderson -The Effect of *Lumbricus terrestris* on Zinc Contaminated Soil
Central Virginia Governor's School

The purpose of this study was to see if there was significantly less zinc in the soil when earthworms were introduced. Three groups (25, 50, and 0 earthworms) with 7 kg of soil each containing 2100 mg of zinc, were tested for zinc over a span of 29 days. After taking eight random soil samples from each bin, the LaMotte Zinc Test Kit was used on day 14 and day 29 to measure zinc levels. After performing a two factor ANOVA and a post-hoc Tukey test, it was determined that the group of 50 earthworms had a significant difference in the levels of zinc after 29 days. The alpha value used was .05. The p-value for columns (days) was .005, and the p-value for sample (zinc levels) was .01. Therefore, the research hypothesis, if *Lumbricus terrestris* are placed into 300 mg/kg of zinc contaminated soil, then they will decrease the amount of zinc in the soil, was supported. The results suggested that earthworms placed into zinc polluted soil will be able to survive and decrease the concentration levels of zinc. Hence, this has implications for heavy metal soil remediation.

William Andrews and Clavio Ascari - Effect of Different Fertilizers on the Vegetative Propagation of *Allium cepa* and to Address Food Waste and Climate Change
Collegiate School

Vegetative propagation is a way of regenerating parts of plants through asexual reproduction. It is a great way to reduce food waste and grow plants from home. Vegetative propagation studies can find ways to lower food waste as well as increase the efficiency of vegetative propagation. If vegetative propagation is more effective, it can lower food waste and address climate change around the world. When food waste is lowered, it prevents food in landfills from decomposing which produces methane. It also prevents fuel consumption that is used to transport waste. In this experiment, we used fertilizers that most people would have available at home that would have a positive effect on vegetative propagation. These fertilizers included an egg shell fertilizer and a bat guano natural fertilizer. Both

fertilizers are known to provide vital nutrients to plants that impact their growth. Food waste can also lead to climate change and extra pollution. Vegetative propagation is a way to lower the amount of greenhouse gasses in the atmosphere and improve air quality. In this experiment, we cut off parts of the green onion plant and placed them in water for 4 days. After the control period, we made separate solutions of bat guano and eggshells and placed 30 green onions in water alone, bat guano, and eggshells for 5 days. Each day we measured the longest root and longest stem of each green onion plant. Our results show that the bat guano propagation solution was the most successful in impacting the vegetative propagation of green onion plants. This benefit is mainly due to the amount of nitrogen that bat guano provides to the plant and that it has a higher solubility that allows it to mix with the roots and provide nutrients. Using vegetative propagation is better for the environment because it lowers food waste which in turn lowers the number of greenhouse gases that are produced through multiple processes.

Maral Ariunbayasgalan and Hanan Abdelbagi -The Effect of Different Levels of Moisture in Grass on the Absorption Rate

Washington-Liberty High School

Droughts can be defined as prolonged periods that consist of moisture deficit and dryness that can happen anywhere in the world for various amounts of time. While droughts are natural disasters, global warming and human activities can worsen the influence and impact of the drought. The purpose of this experiment was to test the effects of varied moisture levels of watered grass on the absorption rate of the soil. The independent variable is the different levels of moisture in the grass. The dependent variable is the absorption rate, measured in liters and milliliters. The experimental variables were grass that is not watered, frequently watered grass, normally watered grass, and over-watered grass. It was hypothesized that if the moisture levels in grass are different, then the normally watered grass would absorb the most water from the flash flood due to the soil being moist enough to soak up more water. The experiment was conducted by constructing a structure that pours one liter of water onto the grown plants individually, imitating a flash flood. Out of all four experimental groups, the results revealed that the normally watered grass was the most successful at absorbing one liter of water. The overly watered grass being was second best. The frequently and not watered grass absorbed the least amount of water, making them the experimental group that absorbed the least amount of water.

Andrew Ascoli - Hidden Contribution of Sodium Sulfate on Cyanobacteria and Eutrophication

Collegiate School

Eutrophication is the accumulation of nutrients inside natural watersheds. Eutrophication is mainly caused by nutrients from excess run-off due to farms and sewage systems. Currently, eutrophication is affecting nearly 40% of natural lakes and reservoirs across the world, so it is an unresolved global problem. Although both phosphorus and nitrogen

are studied closely revolving around the formation of eutrophication, there are few studies based on the relation between sulfates and eutrophication. Sulfates may be hidden contributors to eutrophication, and the limitation of the usage of household and agricultural products containing sulfates may reduce the negative impact of eutrophication internationally. Sodium sulfates are commonly found in detergents and pesticides, both of which contribute to excess run-off into natural watersheds. Bacteria commonly found in eutrophic lakes and reservoirs is Cyanobacteria, and cyanobacterial specimens have been found to be sensitive to sodium sulfate. Cyanobacteria was previously known as blue-green algae because in large blooms, Cyanobacteria turns water green and blue. Although Cyanobacteria cultures are not technically algae, they both negatively affect freshwater sources and contribute to the cause of eutrophication. In this study, two groups of cyanobacterial specimens were grown in a freshwater solution, Spirulina, and Anabaena, both of which are commonly found in algal blooms. There were four cultures in total, two Spirulina cultures, and two Anabaena cultures. One culture from each was kept as a control whilst the other cultures were exposed to 765 milligrams of sodium sulfate every 120 hours. The two cultures exposed to sodium sulfate showed considerable growth and less water clarity, demonstrating sodium sulfate as a hidden contributor to eutrophication. A turbidity sensor was used to measure how turbid each culture was at the end of the experimental period, and the result of this experiment suggests that sodium sulfate is related to and is partially responsible for algal blooms in freshwater sources across the world. Sodium sulfates are commonly found in detergents and pesticides, both of which contribute to excess run-off into natural watersheds; therefore, limiting the usage of household detergents and agricultural pesticides may potentially help resolve the global issue of eutrophication.

Eissa Albathigi -The Effect of Number of Plants in a Model Room on the Temperature of the Room
Clover Hill High School

The purpose of this experiment was to determine the effect of the number of plants in a model room on the temperature. Knowing how plants affect the temperature helps people either add or remove plants in indoor environments. The research hypothesis was: The more plants there were, the lower the temperature would be. To measure the temperatures with each number of plants, the plants and a thermometer were placed inside of clear plastic containers with a hole at the top and were measured every Tuesday and Friday for 4 weeks. They were also watered after each data collection. The five levels of independent variable were the control group (0 plants), 1, 3, and 8 plants in each room. There were 8 trials per level of independent variable and the temperatures were recorded into a data table. The mean results of the rooms with 0, 1, 3, and 8 plants during the first data collection of week 3 were 32.1°C, 32.0 °C, 31.0 °C, and 29.9 °C respectively. Based on the results of a One-Way ANOVA test with 0.05 level of significance, the null hypothesis was rejected. The research hypothesis was supported by the data that was collected.

Jefferson Callis -The Effect of Redlining on Soil Microbial Diversity
Roanoke Valley Governor's School

Redlining, the practice in which the United States government labeled communities of color as high financial risks, was once commonly used by bankers and realtors to justify denying financial services to non-white citizens. Though this practice has now been illegal for over fifty years, certain studies indicate residual effects continue to be experienced in redlined communities, including evidence that higher concentrations of pollutants are present. Due to certain studies which indicate that the excess of pollutants such as carbon dioxide reduce the presence of microbial diversity, it was hypothesized that the soil samples taken from neighborhoods which received high HOLC grades will display higher levels of microbial diversity than soil samples from communities which were redlined. To assess whether redlining has impacted soil microbial diversity, nine soil samples were taken from three neighborhood elementary schools in Roanoke, Virginia. Subsequently, these samples were analyzed using 96-well Biolog EcoPlates™, which indicate how diverse the sources are from which microbes can grow. Following a 144-hour incubation period, the Biolog EcoPlates™ were assessed using a plate reader which provided light absorbance data used to calculate the Shannon diversity index for each site. An ANOVA test was performed to determine whether the differences in the indices' development were significant. Results indicated that soil from redlined communities contain a significantly lower level of microbial diversity than communities which received higher HOLC grades. This is likely attributable to the increased presence of pollutants in redlined communities, though this would need to be confirmed by future testing.

Shane Dunford -The Cathodic Corrosion Protection Capabilities of Sacrificial Anodes in Coastal Areas
Southwest Virginia Governor's School

Sacrificial anodes are highly active metals that protect active metals like steel from corrosion. There was information about how aluminum was the common anode used in offshore pipelines, as well as magnesium and zinc still being the common anodes of choice for galvanic protection of underground structures. However, there was not much information about the performance of the three anodes in protecting an underground structure in the different kinds of coastal soils, an increased salinity environment. The purpose of this experiment was to find out if zinc would provide the best corrosion protection in all of the soil types, if aluminum's performance in the soil would improve, and if clay soil would still cause the most amount of corrosion. Steel, aluminum, zinc, and magnesium pieces grinded to remove existing rust, and weighed. After being weighed, they were connected and weighed again. They were then buried in four common types of coastal soil: clay only, mostly sand, mostly clay, and mostly loam, and given 1.5 oz (ounces) of water that had 12.3g (grams) of NaCl twice a week for five weeks. After five weeks they were dug up and weighed again as well as visually analyzed. The mean change in weight for aluminum was 1.16g, mean change for zinc was 2.50g, and mean change for magnesium was 0.99g. Because of the overall p-value for the experiment (0.7401), there was no significant change recorded during the experiment. This data showed the null hypothesis that all the

means of the sample were equal and did not support that alternative which stated all the means of the sample were not equal. The conclusions were that aluminum's performance in soil did not change, magnesium had the best corrosion protection, and different anodes had different soils that caused the worst corrosion. This data could be used to help anyone with an underground structure in a coastal area by giving them information about which anodes performs better in the type of soil they are trying to work in.

Lincoln Eberly- Effect of Acid Rain on Limestone
Washington-Liberty High School

Acidity of rain was first documented around the Industrial Revolution, and ever since, rain in both North America and Europe has become more acidic. The purpose of this experiment was to find the caliber of erosion that various acidic solutions from 7-pH (control) to 3-pH have on the durability of limestone, imitating real acid rain on buildings across the nation. It was hypothesized that the pH-3 solution would be the strongest of all 5 acidic solutions, because the concentration of acid was greater and therefore would erode more of the limestone. To imitate acid rain, reptile hydration systems were set up to drip the various solutions in pH increments at an equal dripping pace. The limestone pieces were then weighed before being placed under the spouts of the reptile dripping systems. The limestone pieces were then weighed twice after the acid had dripped on them, once when the limestone was still wet, and once when the limestone was allowed to completely dry. The average weight of the 'wet' data was heavier than the starting value, which suggests that the limestone absorbed a little bit of the solution when the acid was applied. Once this limestone was allowed to dry, however, the data supported the hypothesis that the 3-pH solution was the most erosive of the 5 levels, and the null hypothesis was rejected.

Olivia Cozette -The Effect of Different Locations of the Susquehanna River relative to the Conowingo Dam on the Concentrations of Different Chemicals
Washington-Liberty High School

The Susquehanna River is one of the longest rivers along the Eastern seaboard. It flows through multiple states and ends at the northern tip of the Chesapeake Bay. The Susquehanna River provides the Chesapeake Bay with about a little over 40% of its nitrogen loads and 25% of its phosphorus concentrations. Although a dam, called the Conowingo dam, has been placed to trap this pollution, recent studies have proved that it has reached 96% of its capacity and is no longer functioning as well as it should be. The purpose of this study was to test the water quality at different locations along the Susquehanna River to determine the functionality of the Conowingo Dam and where the pollution has accumulated the most. The different locations tested were 200 meters before the dam, right before the dam, right after the dam, and 200 meters after the dam. The chemicals tested were phosphorus, nitrates, nitrites, and dissolved oxygen. It was hypothesized that the water tested right before the Conowingo dam would contain the most nitrate, nitrite, and

phosphorus concentration and least dissolved oxygen, because the Conowingo dam has reached 96% capacity and has proven it can no longer capture pollution flowing downstream. The experiment was conducted by collecting and testing 10 samples of water at the 4 different locations and testing the concentrations of phosphorus, nitrates, nitrites, and dissolved oxygen. The results showed that for the pollutants (phosphorus, nitrite, and nitrate), the concentrations were at their highest just before the dam and at their lowest right after the dam. For dissolved oxygen, there was the most right after the dam with 0.88 PPM. The data collected suggests that the dam is indeed still effective although many of the pollutants accumulate right before it.

Environmental & Earth Science B (HS ENV-B)

First Place

Hamza Lateef - Mapping Changes in Particulate Pollution and Plant Health in the Indian Sub-Continent During the COVID-19 pandemic
Governor's School @ Innovation Park

Particulate matter (PM) air pollution is ranked the 13th leading cause of mortality across the globe. Lockdowns during the COVID-19 pandemic provided a unique opportunity to assess the potential beneficial impact on air quality and possibly biologic outcomes. The main objectives of this project were to utilize NASA satellite-derived data and: 1) Observe changes in PM 2.5 across four countries, in the Indian sub-continent, before the outbreak of COVID-19 and through the observed case peak months in 2020 and 2021; 2) Examine changes in normalized difference vegetation index (NDVI) during, around, and subsequent to COVID-19 peak months; 3) Evaluate changes in precipitation and land surface temperature as other potential contributors to changes in plant health. Remote sensing datasets included "Aerosol Optical Thickness" to measure air pollution, and "Normalized Difference Vegetation Index" to examine vegetation health. We found that PM 2.5 concentration substantially decreased in some areas of the sub-continent, during the peak months, while NDVI improved. While accompanying precipitation and land surface temperature may account for some of the changes in NDVI, they alone cannot explain the improvement in plant health during shutdowns. Thus, at least some of the decreased plant stress may be attributed to lower emission of atmospheric pollutants, including PM 2.5.

Second Place

Flora Freer -The Effect of Water Depth in the Swift Creek Reservoir on the Amount of Microplastics Collected at Various Depths
Clover Hill High School

Microplastics are widespread throughout the environment and can have many harmful effects, prompting the need for cleanup strategies. Identifying where microplastics accumulate is necessary for cleanup efforts to be efficient and effective. The question researched was the effect of water depth in the Swift Creek Reservoir on the amount of microplastics collected at various depths. Microplastics were collected in 10 trials using a 333-micron mesh plankton net at four different depths: 1 meter, 2-meter, 3-meter, and the surface used as the control. The samples were sieved and preserved in isopropyl alcohol, then analyzed under a microscope at 40x magnification using a grid filter. The number of microplastic particles, the surface area of plastic, and the type of microplastic was recorded. The median

number of particles collected at the surface, 1 meter, 2 meter, and 3-meter depths were 29.0, 24.5, 34.5, and 22.0, respectively. The median surface area of plastic was 21.8220 mm, 16.4880 mm, 23.0165 mm, and 21.8625 mm for the surface, 1 meter, 2 meter, and 3-meter depths, respectively. Microfibers were the most abundant type of microplastic, making up 77.50% of the total microplastics. Films were the second most abundant (16.69%), followed by microbeads (2.67%), fragments (2.27%), and foams (0.87%). The hypothesis was: If microplastics were collected at different water depths, then the deepest depth - above the sediment - would have the most microplastics because denser microplastics would sink and less dense microplastics would begin to weigh more because of biofouling and sink as well. The data did not support the hypothesis. The 2-meter depth had the greatest number of particles and surface area. The null hypothesis of no significant difference was tested using a one-way ANOVA test and was not rejected.

Third Place

Shreya Lal -The Effect of Exposure to Activated Sludge Bacteria on PET
Mills E. Godwin High School

The omnipresence of plastics (inorganic material requiring years to decompose) within environments has caused adverse effects regarding all biological levels of organization. Studying methods of biodegradation presently implemented, such as anaerobic digestion, allowed applications of practical means to disrupt the cycle of plastic pollution. The experiment observed anaerobic-activated sludge bacteria's capabilities as a biocatalyst in removing polyethylene terephthalate (PET). It was hypothesized that longer exposure to the bacteria would result in more significant biodegradation of the plastic. A control was not identified, because the experiment observed changes in mass over progressive amounts of time (six, nine, 12, and 15 days), therefore the experimental groups were compared directly rather than to a control group. The anaerobic sludge sample was collected from the mesophilic anaerobic digester at a municipal wastewater treatment plant in Fairfax, Virginia. The bacteria were exposed to PET plastic for varied durations (six, nine, 12, and 15 days) to examine their change in mass, measured by the difference between the after-exposure and initial masses. It was observed that no reduction of PET occurred under the experimental conditions, as the mean of each independent variable showed a gradual increase in mass as exposure increased. However, an inferential analysis demonstrated that the data may have been statistically insignificant and the increase in mass was likely due to bacterial adhesion to the sheets as the duration of exposure increased.

Honorable Mention

Payton Heimbach -The Effect of Triclosan on The Mortality Rate of *Daphnia magna*
Central Virginia Governor's School

The purpose of this experiment was to determine whether the common antimicrobial chemical triclosan had a negative effect on the life span of *Daphnia magna*, and therefore contributes harm to aquatic ecosystems. The study was conducted in a local high school laboratory during Fall of 2022. *Daphnia magna* culture from Carolina.com was used in this experiment. The *D. magna* were divided between three groups. Each group was placed into separate beakers with spring water and each vial contained a different concentration of triclosan. Rates of decline within the populations were measured over a span of three weeks, by analyzing population sizes every few days. A One-Factor ANOVA test was run to determine significance between the mean decline rate of each concentration group. The test returned a p-value of .0013 with an alpha value of .05. After performing a Post-hoc Tukey Test to determine which groups the significance lies between, differences were found between the control group and the lower concentration group of 10µg/L, as well as the control group and the higher concentration group of 25µg/L. This indicated that the data was significant and therefore the research hypothesis, which stated that if triclosan was added to the environment of the *D. magna*, then they would experience higher die-off rates, was supported. In conclusion, triclosan had significant negative effects on the lifespan of *D. magna*, inferring that the chemical may have detrimental effects on natural populations and affect the overall health of an aquatic ecosystem.

Honorable Mention

Anika Kamujula – The Effect of Varying Concentrations of Copper on Spirulina Growth
Mills E. Godwin High School

The purpose of this experiment was to explore how copper will impact the growth of Spirulina. Many communities globally use untreated water sources including wells and lakes daily. Copper has antibacterial properties which can be used in water treatment. For the experiment, 12 mL Spirulina samples were treated with 60 x 10 mm and 80 x 10 mm copper pieces for 7 days. The control group was Spirulina not treated with copper. To compare the concentration of Spirulina, the difference between the initial and results for each trial group was measured. It was hypothesized that if the Spirulina sample is exposed to an 80 x 10 mm copper piece, then the Spirulina will grow less than without any copper. The results found that there was an increase in absorbance of 0.166 Au in the control group. The average absorbance of the independent variable 60 x 10 mm (-0.007 Au) decreased 0.001 Au more than the average absorbance of the independent variable 80 x 10 mm (-0.006 Au). A t-test was conducted and determined that the data was not significant for 60 x 10 mm vs. 80 x 10 mm. The hypothesis is not supported by the results because the data exhibits that though exposure to copper decreased Spirulina growth, most was decreased with a 60 x 10 mm strip. This research can lead to research on how copper can be used to treat other bacteria in water and as larger-scale commercial water treatment plants.

Honorable Mention

Annie Eubanks -The Effect of Ammonium Hydroxide on Freshwater Algal Biomass
Mills E. Godwin High School

This experiment aimed to examine the effects of ammonium hydroxide on the biomass of *Chlorella vulgaris* freshwater algae. The initial objective was to determine a threshold for the maximum allowable concentration of inorganic nitrogen that can be included in agricultural and industrial products to minimize anthropogenic nitrogen pollution and its subsequent effects on coastal ecosystems, which has applications in the prevention of eutrophication and continued support of biodiversity within coastal ecosystems. Algal biomass was measured via chlorophyll-a concentration, which was determined by absorbance readings for algae samples in each experimental group—0% control, 1% ammonium hydroxide, and 2% ammonium hydroxide—at 664 nm using a spectrophotometer after 24 hours of exposure to the chemical. It was hypothesized that algae samples treated with the 1% solution would yield the greatest biomass; however, upon experimentation it was discovered that the 2% group had the highest algal biomass, with the 1% group in the middle and the control group having the lowest biomass, indicating that algal biomass varies directly with concentration of ammonium hydroxide. This data did not support the research hypothesis, and a t-test determined the results to be significant at a 0.05 level. It was thought that the results are due to the role of ammonia as the preferred form of inorganic nitrogen for uptake and assimilation, which facilitates the breakdown of nitrogen into amino acids that promote the growth and proliferation of the algae.

Julian Eichers -The Effect of Harmful Algal Blooms on the Population of North Atlantic Right Whales
Arlington Tech

This project has a goal of determining the possibility of a cause of death of North Atlantic right whales, given a correlation. It was hypothesized initially that there would be a negative correlation between the population of North Atlantic right whales, and the rate of observed Harmful Algal Blooms (HABs) in the area occupied by North Atlantic right whales. The null hypothesis has been rejected. The portion of deaths of this species with a population estimate currently ranging from 300 to 400, is relatively high. A correlation between these death rates and the rate of HABs may display that there is reason to research further. The rate of HABs was determined using the United States Harmful Algal Event Database (US HAEDAT), as well as the Canadian Harmful Algal Event Database (CA HAEDAT). This data required compilation, as there was not specific data within the region considered to be the habitat of the North Atlantic right whale. The population of the North Atlantic right whale, as well as the rate of North Atlantic right whale deaths with indeterminate cause of death, came from the Marine Mammal Commission and NOAA. In Model #1, it was found that there was a positive correlation between the population of the North Atlantic right whale and the rate of HABs from 1990 to 2020. There was much variation between each data point, and this was also true of the second model. In Model #2, it was found that there was a positive correlation between the rate of death with indeterminate cause of North Atlantic right whales, and the rate of HABs from 1990 to 2020. In this case, the standard deviation of 1.77 was

higher than the mean of 1.3, showing the extreme lack of data. Model #1 does not reject the null hypothesis, while Model #2 does. This project led to the conclusion that there is reason to perform further research, as the data sets were simply too small, or too inaccurate to collect valuable information via the use of statistical tests.

Chelsea Erwin - Detection of Microplastics in the Virginia Peninsula
Hampton Roads Academy

Micropollutants are extremely dangerous and due to the difficulty in detecting micro- and nano- plastics in water, much of the general public is unaware of the impact these particles have on our everyday life. With the exponential production of plastics worldwide, the goal of this project was to increase awareness of unseen plastic presence in our local waterways. Twelve water samples were collected and filtered through a 55-micron net. The net was soaked overnight in hydrogen peroxide (H₂O₂) to digest any organic materials in the water. The samples were examined for microplastics using a stereomicroscope under UV light. Of the 12 samples tested, 10 were found to contain various amounts of microplastics including samples from the York and James Rivers. It was concluded that these micropollutants were present, and more commonly found near water sources where human presence was active, while local water treatment plants of the York and James Rivers were proven to help filter and clean these waterways of these dangerous pollutants.

George Sherlin -The Effect of Various Antioxidants on the Growth of *Medicago sativa* in a Saline Environment
Mills E. Godwin High School

The purpose of this experiment is to observe the effects of various antioxidants on the growth of *Medicago sativa* in a saline environment. Soil salinization has become a global issue, as salty soils decrease agricultural yield in semi-arid and coastal areas. Leaching or flooding the soil, have been temporary, expensive solutions to salinity. Antioxidants have been shown to improve tolerance to salt stress in plants by alleviating reactive oxygen species. *M. sativa* was cultivated in saline conditions and germinated for 7 days and then treated with Vitamin C, Vitamin A, Vitamin E, or Alpha Lipoic Acid, through foliar application and a second treatment was applied after three days. After data collection and calculation of the mean, the highest average growth was seen in samples treated with ALA, while the least growth was seen in samples treated with Vitamin A. An explanation for ALA's success is that it induces the production of the other antioxidants in the plant, as opposed to the plant solely receiving the benefits of ALA. It was hypothesized that if ALA was applied using foliar application, it would show the greatest growth in *M. sativa*. The greatest standard deviation was seen in Vitamin C, while the least standard deviation was seen in Vitamin A. The data was significant for samples that received Vitamin C and Alpha Lipoic Acid, showing that these antioxidants influence plant growth. Recommendations for further study include the combination of antioxidants or the use of the antioxidants in different quantities based on the antioxidants found in the plant's environment.

Erik Graulich -The Effect of Biocide Type and Concentration on Hull Fouling and Exposed Estuarine Crustaceans
Chesapeake Bay Governor's School

Hull fouling occurs as organisms attach themselves to ships' hulls impacting the hydrodynamics, decreasing fuel economy by 1-2%, and reducing maneuverability. To combat hull fouling and its associated problems, special antifouling paints are applied to the lower submerged portion of the hull on all ocean-going vessels. Today the majority of antifouling paints use the copper-based chemical biocide, cuprous oxide (Cu_2O), as the main active ingredient. These metal-based biocides have been found leaching into local waterways as well as affecting the soil in boatyards and marinas and damaging invertebrate populations. This project compares an alternative bottom paint solution designed to lower the environmental impact of the copper based bottom paint on the surrounding ecosystem. After being submerged in the Elizabeth River for 10 weeks, the control group had a higher percent coverage than all of the painted treatments. The 0% 'Eco' Cu_2O , 46% Cu_2O , and 61% Cu_2O treatments were all similar in coverage, with no live organisms visible on the painted surfaces. Mud crabs and grass shrimp were subjected to a 48-hour survivorship exposure to water exposed to the painted surfaces. The mortality rate of the control was 25% while the 'eco' 0%, 46%, and 61% treatments had a mortality rate of 66%. Understanding the impacts and reducing the use of these deadly biocides to the absolute minimum is critical to protecting the estuarine environment for a healthy Chesapeake Bay.

Courtney Harrow -Finding A New Home for Chesapeake Bay Oyster Spat
Chesapeake Bay Governor's School

Oyster populations in the Chesapeake Bay estuary are in a steep decline for over 200 years due to overharvesting and diseases. Efforts of restoring the oyster population begin with substrates which create the most suitable environment for wild spat. The purpose of this study is to determine the most effective substrate when restoring the Chesapeake Bay oyster population. Five substrates were used in determining the most suitable for oyster restoration: plastic, granite, spat oyster shells, large oyster shells, and live oysters. Three spat bag samples were placed in the three locations, two containing all substrates except live oysters, and one containing only live oysters. Across the samples, spat bags with the presence of only live oysters showed a 18.65 percent difference compared to the samples without the presence of live oysters. The data yielded a $p = .21735$ when live oysters were present. When analyzing the substrates without the presence of live oysters, the data yield a $p = .27510$. The different sites were significant in the spat collected with a $p = .08535$. It is crucial to continue restoration of the oyster population due to the benefits of carbon sequestration and water stabilization oysters provide. This study provides further research on the most effective substrate when restoring the oyster population.

Holly Haydon - Iron and Copper Concentration Effects on Brine Shrimp Hatching and Mortality
Chesapeake Bay Governor's School

This study compares the effects of copper and iron pollutants on brine shrimp hatching and mortality. Studies have shown certain levels of these toxins are harmful to humans, it is also important to see how other organisms at the base of the food web, are affected. Brine shrimps are widely used in toxicity experiments because they easily hatch from dry cysts, and are a good indicator species to determine the health of a lake. Based on past experiments it was hypothesized that copper (II) sulfate would have the greatest impact on the brine shrimps hatching and mortality. To test this hypothesis, nine beakers filled with 500ml of 35ppt saltwater and 8.5ml of brine shrimp were placed in three groups of three. Three of the beakers were contaminated with 0.030 grams of solid iron (III) nitrate, three with 0.030 grams of solid copper (II) sulfate, and three were the control with no heavy metal contaminants added. Brine shrimp exposed to iron (III) nitrate had the greatest hatching rate, but a higher mortality rate than the control. The groups exposed to copper (II) sulfate had the greatest mortality and data also showed that when exposed to copper (II) sulfate, the brine shrimp cyst hatch prematurely, resulting in the brine shrimps' death. This experiment produced significant p-value evidence to support the claim that iron and copper have a significant effect on brine shrimp hatching and mortality.

Jacey Hendrix - Is the Radford Army Ammunition Plant Polluting the New River?
Southwest Virginia Governor's School

The Radford Army Ammunition Plant (RFAAP) manufactures firearm ammunition and rocket propellants in Radford, Virginia. The plant uses large amounts of water from the New River in their manufacturing processes. This allows heavy propellant metals, chemicals, and other harmful materials to contaminate the water before wastewater treatment. To find out if the RFAAP's production of propellants is polluting the water supply, sixteen water samples were collected for testing. There were four collection locations, two upstream and two downstream. The upstream locations were the Dedmon Center at Radford University and the Pepper's Ferry Bridge. The downstream locations were the Whitethorne Boat Ramp, which is just below the RFAAP, and public river access in Parrott. The samples were filtered to remove large solids, and then acidified with concentrated nitric acid to preserve any elemental components. The water samples were given to Inorganic Ventures, where they were transferred into test tubes and run through an Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) instrument. The elements that were found significantly different upstream and downstream by statistical analysis were magnesium, strontium, and sulfur. Runoff from farms using sulfur-based fertilizer is a possible cause of the high sulfur concentrations. The mouth of Tom's Creek, which runs through the town of Blacksburg, is just above the Whitethorne Boat Ramp, could be a cause of sulfur and magnesium as well. Although arsenic is not significantly different upstream and downstream, all concentrations found are two to three times higher than the safe drinking limit. The arsenic values indicate that the river area is not safe for fishing, recreational swimming, or game hunting. Future research and testing is required to determine where these elements are coming from and how to manage their concentrations in order to keep the New River safe.

Rishab Kambham -The Effect of Air Particle Size on Air Filter Efficiency
Mills E. Godwin High School

The purpose of this experiment is to determine if the air particle size has an effect on the efficiency of the air filter. Air filters are an important tool for allergy prevention, as they are used in many households, and may filter different particles at varying levels of efficiency. The experiment involved filtering air, cornstarch (25 μm), and powdered sugar (50 μm) for intervals of five minutes per trial. The parts per million (ppm) was measured before and after the filter was turned on. The control used was air. It was hypothesized that the smallest particle (cornstarch) would be filtered most efficiently. The results show that, on average, cornstarch was filtered the best with 96.390% of particles that were released were filtered. A t-test was done and it determined that all the data was significant. The results supported the research hypothesis. It is believed that the results are due to the fact that the lighter and smaller particles are easier to be pulled into the filter, thus being easier to filter. This research could lead to further studies on the relationship between air filters and allergens along with looking into the most effective filters for VOCs and pollutants.

Nihita Korrapati -The Effect of Various Water Contaminants on the Corrosion of Iron
Mills E. Godwin High School

One of the primary reasons for issues with the durability of water, sewage, oil, and gas distribution systems is the corrosion of ferrous metals. The detrimental effects of corrosion have grown to be a significant issue on a global scale. The main cause of the deterioration of underground pipelines was found to be corrosion. The purpose of this experiment is to identify if common water contaminants affect the corrosion of iron, specifically for the usage of water pipes and drainage systems. Testing how water contaminants affect corrosion can determine which water contaminants affect the corrosion of iron the most, and which ones can be used when observing metal water pipes for everyday use. The hypothesis of this experiment is that if iron was soaked in Bleach, then it will cause the most corrosion to occur. This was inferred due to the pH and usage of bleach in water pipes. To test the corrosion of iron in various chemicals, iron nails were placed in either hydrochloric acid, bleach, pesticide, or water. After one week, the results were collected by measuring the mass in grams. The initial and final mass of the nails were then compared and analyzed. The results showed bleach had the greatest impact on the corrosion of iron. T-tests were performed to calculate the significance of the data. For further study, the effects of corrosion in soil environments could be studied. Furthermore, an experiment to test the which chemical prevents the corrosion of iron could be conducted.

Environmental & Earth Science C (HS ENV-C)

First Place

Aarav Patel & Michael Day- Research of The Novel Production of Organic-Based Amino Acid Incorporated CO₂ Absorbing Hydrogels
Governor's School @ Innovation Park

The excessive release of Carbon Dioxide into the atmosphere is a significant environmental concern that elevates global temperatures, compromises air quality, and increases the risk of respiratory disease. Utilizing chitosan-alginate hydrogels incorporated with amino acid aqueous solutions, the hypothesis that these polymerized structures will reduce the carbon concentration in a controlled environment was tested. The hydrogel structure was formed with chitosan and alginate. Chitosan, having the characteristics of a biopolymer, offers high biodegradability making it ideal for hydrogel creation. Similarly, alginate was chosen due to its low toxicity, biocompatibility, and structural integrity making it efficient in retaining carbon. An aqueous solution of two different amino acids was mixed with a buffer solution to maintain optimal pH. To evaluate the hydrogels, a CO₂ pad was placed in an airtight container for 15 minutes simulating an industrial plant's atmosphere, and carbon concentration was recorded via a sensor. After 15 minutes, the hydrogels were placed in the container, and CO₂ levels were monitored every 5 minutes for 45 minutes. The experimental data showed minimal CO₂ absorption 30 minutes after the initial placement of the hydrogels in the container. The glycine-proline-infused hydrogels effectively decreased CO₂ levels by more than 15%, with an average decrease from 626 ppm to 529 ppm. This research demonstrates that the incorporation of amino acids into chitosan-alginate hydrogels can serve as a viable solution for reducing carbon concentration under regulated conditions. To further reduce carbon concentration, future experiments will investigate the use of additional amino acids in conjunction with hydrogels.

Second Place

Elle Pickard - Determination of Per- and Polyfluoroalkyl Substances, Nitrates, and Phosphates in Different Locations on the Potomac River
Washington-Liberty High School

The Potomac River has long stood as an important waterway for our nation. However, it is notorious for its historical anthropogenic pollution and dangerous conditions for humans as well as wildlife. Cleanup efforts have made progress since the 1950s, but the river still needs rehabilitation today. An emerging contaminant class of concern is a group of chemicals widely known as "forever chemicals". Forever chemicals, or per- and polyfluoroalkyl substances (PFAS), are manufactured compounds that can cause serious health effects in humans as well as wildlife. This experiment was

conducted in order to analyze the state of the Potomac River's PFAS pollution and to determine the levels of these chemicals at different points downstream. Water from three locations on the river (Great Falls, National Harbor, and Mason Neck) was collected and tested for PFAS with a solid phase extraction (SPE) technique and a liquid chromatography-mass spectrometry (LC-MS) machine. The PFAS results showed that the lowest concentration was at Great Falls, which was furthest upstream, followed in succession by National Harbor, located in the middle, and then Mason Neck, the furthest downstream sampling site. In addition, nitrate and phosphate results were similar, with concentrations increasing as the sample sites progressed downstream. Alarmingly, each location exceeded safe concentrations of chemicals for river water. This correlation suggests that, as water flows further downstream, one would expect pollutants, including PFAS, nitrates, and phosphates, to become more and more concentrated.

Third Place

Ananya Nanduru -The Effect of Titanium Dioxide (TiO₂) on the Levels of Dissolved Oxygen Produced by *Thalassiosira*
Mills E. Godwin High School

The purpose of this experiment was to determine the effects that Titanium Dioxide had on diatoms. Phytoplankton such as diatoms are the primary producer of oxygen in the environment, and they must be protected in order to ensure the safety of marine ecosystems, as they are at risk of hypoxia, which is when oxygen resources are depleted in an area. A research hypothesis was formulated that if *Thalassiosira* are exposed to 0 mL of Titanium Dioxide, they will have the highest concentration of dissolved oxygen, because the Titanium Dioxide cannot present any adverse effects. Various concentrations of TiO₂ powder were tested using test tubes, placed in sunlight to stimulate both photosynthesis and ultraviolet radiation caused by the photocatalyst that TiO₂ behaves as. The control in the experiment was a group with no added Titanium Dioxide. It was found that as the concentration of Titanium Dioxide increased, the average concentration of dissolved oxygen decreased, implying that there is an inverse relationship with TiO₂ concentration against dissolved oxygen concentration. In addition, all the data was found to be statistically significant due to the independent variable, meaning Titanium Dioxide did have a substantial effect, due to its function as a photocatalyst. Furthermore, this experiment allows opportunities for alternate studies on the same topic, including other organisms and other contaminants. In conclusion, this research and similar projects are necessary to prevent hypoxia in marine ecosystems and other larger-scale effects.

Honorable Mention

Riley Morford-Comparing Biosorption Capabilities of Lead (II) Acetate Trihydrate by *Spirulina platensis* and *Chlorella vulgaris*.
Central Virginia Governor's School

The purpose of this study was to determine which algae species, *S. platensis* or *C. vulgaris*, is superior in the biosorption of lead (II) acetate trihydrate. The two algae samples were cultivated for four weeks before 500 algal beads were created by dropping an algae-sodium alginate solution into a 3% calcium chloride solution. Ten trials were conducted for each of the three groups: *S. platensis*, *C. vulgaris*, and control. Twenty-five algal beads were placed in each sample, except the control group which received none, and left to sit in the lead solution for two weeks. Lead test strips were used to collect data on lead biosorption. The algae samples were then observed using six disposable hemocytometers which allowed accurate cell counts and calculations to determine single cell biosorption. *S. platensis*, on average, biosorbed the most lead ($M=76$ ppm), *C. vulgaris* biosorbed the second most ($M=66$ ppm), and the control group biosorbed none of the lead ($M=0$ ppm). A single-factor ANOVA was used to determine that the remaining lead concentrations indicated significance as the p-value of 2.27×10^{-19} was more extreme than the alpha ($\alpha = .05$). The subsequent post-hoc Tukey test suggested that all the groups were statistically significant. The research hypothesis that *C. vulgaris* would biosorb the most lead was not supported because *S. platensis* ultimately displayed the highest biosorption. While *S. platensis* was suggested to be the most optimal biosorbent of lead (II) acetate trihydrate, *C. vulgaris* similarly shows a high capacity for heavy metal bioremediation.

Honorable Mention

Joshua Mayer - Comparing the Growth, Mass, and Survival Rate of Oysters Raised Using the Standard and RAS Methods
Chesapeake Bay Governor's School

Mass mortality events of larval oysters in oyster hatcheries have become more common due to increasingly acidic seawater pumped into aquaculture facilities. Using a recirculating aquaculture system (RAS), hatcheries could isolate shellfish larvae from harmful water quality events. Delicate larvae could be reared through their vulnerable stages, until they develop enough to be more resilient to the effects of acidification. An RAS uses highly filtered water that constantly recirculates through a treatment system that removes biosolids, harmful chemicals such as ammonia (NH_3), and adds dissolved oxygen (O_2) so the water has a constant excellent quality. In this study, there were two treatment groups: one using the Standard flow through method and another using the RAS method. The oysters were initially raised at the Oyster Seed Holdings hatchery for 20 days before the larvae were transported to the Acuff Center at the Virginia Institute of Marine Science to be measured. The RAS measurements were significantly greater than the standard measurements for length ($p=0.0032$), width ($p=0.016$), height ($p=0.0038$), and mass ($p=0.0048$). A t-test performed on the survivorship data shows that the RAS values are not significantly greater than the standard values with $p=0.071$ but are approaching significance. The results of this experiment show that RAS aquaculture produces oyster seed that performs comparably with Standard seed. RAS is a viable method for oyster hatcheries to isolate growing oyster larvae from the effects of acidified waters and other harmful events like harmful algal blooms.

Phobe Merritt -The Effect of Acid Rain on Microgreen Radish Seed Germination
Washington Liberty High School

Acid rain is produced from the combustion of fossil fuels, and results in rainwater that consists of a pH value of 5.2 or below. These low pH values are harmful to the environment as they are able to destroy entire ecosystems by stripping soil of vital nutrients, leaving trees barren of bark and leaves, as well as acidifying bodies of water to the point where no marine life is able to survive. The purpose of this experiment was to determine how varying pH values of acid rain affect seed germination. The pH values tested were 4.99, 4.00, and 3.05, while the control was a 5.62 since that is the usual pH of rainwater. It was hypothesized that the pH of 3.05 would yield the least productive germination as the low pH would have caused multiple metabolic process to malfunction and the growth of the plants would falter as a result. The experiment was conducted by allowing 20 microgreen radish seeds to germinate inside a grow-mat with a certain pH level for 21 days. The average growth of each pH level was recorded after the experiment concluded, and the results showed that the pH of 3.05 had the least effective germination with a mean growth of 25.0 millimeters (mm). In contrast, the control (a pH of 5.62) had a mean growth of 58.3 and showed the most effective germination overall. The data collected suggests that lower pH values generate less healthy plants by disrupting seed germination. This experiment provided further insights into how acid rain is a concerning environmental threat that is able to cause detrimental environmental consequences.

Siobhan O'Casey & Natalia Ridgeway -The Effect of Oysters on the Filtration of Water
Washington-Liberty High School

The purpose of this experiment was to determine the effectiveness of oysters on pH, nitrate, and dissolved oxygen levels. The hypothesis of the experiment was that if tested the dissolved oxygen, nitrogen, and pH level of the Potomac River when introduced to oysters, then the water with 5 oysters will have a pH closest to the range of 7-9 which is ideal for the aquatic life, a minimal amount of nitrogen, and a dissolved oxygen level around 6.5 to 8 ppm because oyster are known as a natural filter. Oysters are most known for their ability to get rid of nitrogen in water sources. The hypothesis was not totally supported, there was statistical significance and positive outcomes of the independent variable group with five oysters but for both nitrate and dissolved oxygen levels it was out beaten by the other independent variables. For pH the group with five oysters had the most success then followed by the group with one oyster. The data with the closest to the nitrate desired level was most closely collected by the group with three oysters. The group that reached closest to the desired dissolved oxygen level was both the group with one and zero oysters. There was statistically significant data collected for the mean over the days for pH and dissolved oxygen, while the nitrate means were not statistically significant. The data was possibly reached due to testing methods. The experiment could be improved by trying a larger scale model, running more tests, and different types of oysters. Further tests should be conducted on feed and healthy oysters which was not able to be concluded due to the nature of how this experiment was conducted.

Grihith Makineni -The Effect of Different Filters on Substance Amount in Water
Mills E. Godwin High School

The current experiment was conducted to analyze the effect of different water filters on the amount of substances in water. The quality of water has always been an area of importance for various countries as over 800,000 people pass away yearly due to poor water quality. Water filtration is one solution to enhance water quality, and in the field of water filtration carbon filters, reverse osmosis filters, and Brita water filters had satisfactory performances. 1-Inch-long Chlorine tablets were dissolved in 9-ounce cups of water for one hour, and then filtered out by the three filters. The PPM of each cup was then measured by a PPM machine. The control group in the experiment was a pitcher with no filter. The hypothesis formulated was that reverse osmosis filters would have the least amount of substances in water. The results displayed that the reverse osmosis filter had the lowest amount of substances in the water with 66 PPM. The Carbon filter had the highest standard deviation and variance making it the least precise, while the other filters had relatively better precision. 6 t-tests were calculated for the data, and they suggested that all of the data was significant. The results supported the research hypothesis that was made. The final results are caused by the fact that reverse osmosis filters push out water with pressure, which causes fewer substances in the water. The study done in the experiment would allow scientists to enhance present filtration methods for better quality water.

Wealeigh Loos -The Effect of Heat Stress on *Solanum lycopersicum L.*
Central Virginia Governor's School

The purpose of this research was to determine whether higher temperatures had an effect on *Solanum lycopersicum L.* growth and mass. Plants were placed in growth tents with controlled environments. They were then subjected to different temperatures including 25°, 36°, and 39° C. These temperatures were controlled with ceramic reptile heat lamps and heat mats designed to help with seed germination. The plants' heights were recorded at the end of each week for three weeks, and the biomasses were measured at the end of the study. A single-factor ANOVA test was utilized to analyze the data, which provided p-values of 6.7×10^{-4} and 4.44×10^{-6} , respectively. When compared to the alpha level of .05, this showed that the results were statistically significant. Following this, a post-hoc Tukey test indicated there was a significant difference in biomass between 25° C and 36° C, as well as between 25° C and 39° C. A Tukey test on the height data confirmed a difference between the 25° C and 39° C groups, and between the 36° C and 39° C groups. The results of this experiment supported the research hypothesis, which stated that when plants were exposed to higher temperatures, their growth and biomass would decrease. This research can be utilized in further studies of the effects of climate change.

Kayleigh Miller -The Impact of Shoreline Hardening on Nearshore Fish Populations
Chesapeake Bay Governor's School

Shallow water shorelines are vital habitats for many fish and invertebrate species of the Chesapeake Bay. The small fish species that depend on this habitat are the primary food for larger, more economically important fish species. Human shoreline engineering has built hardened structures like rip rap and altered the shoreline. This study focuses on fish abundance and diversity of three shallow water beach sites in the lower Chesapeake Bay with varying degrees of shoreline engineering from natural to all rip rap. Seine net tows were pulled approximately 20 meters perpendicular to the shoreline to sample the nearshore shallows. All fish and invertebrates caught were collected and photographed to determine abundance and species diversity. At New Point, the natural site, the mean fish catch was 18.5; at Haven Beach, intermediate, the mean fish catch was 16; and at Cappahosic Beach, all riprap, the mean fish catch was 1. At New Point, the mean Shannon Diversity value was 1.38; at Haven Beach, the mean was 0.474; and at Cappahosic Beach, the Shannon Index value was 0. Based on these results, there was no statistical difference in fish abundance between natural and engineered shorelines, $p = 0.3301$. However, results between natural New Point Comfort and hardened Cappahosic Beach yield an ANOVA of $p=0.0733$, suggesting further study is needed. A recommendation is to create living shorelines instead of hard riprap to improve nearshore habitats, improving fish populations and seafood harvests for decades.

Khalia Morris-Impact of Beaver Dam on Water Quality
Chesapeake Bay Governor's School

This paper studied the water quality (dissolved oxygen, turbidity, and flow rate) of two streams; one with a beaver dam and one without. Beaver dams have been shown to help control soil erosion, drought prevention, and reduce flooding. Dams slow down water, and the combination of the water and wood provides different water temperatures and hiding places for many species compared to a flowing stream or pond without beaver activity. Dissolved oxygen was studied by the titration method, flow rate was the float method and turbidity using a turbidity tube. Data was collected twice a month for 4 months totaling eight data collection days. Results showed the beaver dam stream having lower dissolved oxygen than the non-beaver dam stream. The results were statistically significant but supported the non-beaver dam stream as having better dissolved oxygen. The beaver dam stream had statistically lower turbidity supporting the beaver dam stream as having better turbidity levels. There was no difference between flow rates. The results for dissolved oxygen and turbidity were both statistically significant, the turbidity data supported the hypothesis that the beaver dam stream had better water quality.

Quynh Nguyen - Using Activated Charcoal Powder as an Eco-Friendly Sorbent for Oil Spillage Treatment
Mills E. Godwin High School

The paper illustrates the application of activated charcoal powder (PAC) in marine oil spill cleanup and evaluates the impacts of contact time on the oil adsorbent performance of sorbent bags containing activated charcoal. The

physiochemical changes facilitated by the thermal modification process and chemical activation during its production allow activated charcoal powder to have a great surface area, high microporous ability, and complex surface functionalization, all of which make it a good potential sorbent for wastewater and oil spillage treatments. In the experiment, sorbent bags containing activated charcoal powder were placed in a simulated marine oil spill for 10, 15, and 30 minutes. The untreated oil-water solution was used as a negative control. Data collected from the experiment was used to assess the dynamic oil retention capacity of activated charcoal powder, as well as the sorbent's adsorption efficiency. Statistical analysis of the results found that an increment of 15 or 20 minutes in the contact time interval would induce a significant improvement in the activated charcoal's percentage removal efficiency, as well as a significant decline in the charcoal's oil sorption capacity (g/g) over time. Due to its natural oleophilic property and good adsorption ability, the activated charcoal powder was determined in this study as a more sustainable alternative to nondegradable synthetic sorbents in retrieving oil from oil-water emulsions commonly associated with offshore oil spill incidents.

Madison Mussatt -The Effect of Ultraviolet Filter Chemicals on Planarian Health
Mills E. Godwin High School

The purpose of this study is to determine if the UV filters in everyday sunscreens should be removed, and if an alternate source should be evaluated for the protection of wildlife. UV filter chemicals such as octinoxate, avobenzone, and oxybenzone have been shown to have detrimental effects on wildlife, therefore the experiment was conducted to conclude if these UV filters had negative side effects on planarian. It was hypothesized that if planarian were exposed to oxybenzone, octinoxate, and avobenzone, then the planarian exposed to oxybenzone would experience the most detrimental side effects. The experiment occurred for five days and consisted of four groups planarian being exposed to solutions of 0.01 mg of the UV filter chemical dissolved in 100 mL of water, then daily observations of health being recorded. A control of 100% spring water was implemented alongside the oxybenzone, octinoxate, and avobenzone to ensure reliability of the results. Chi-square tests were performed on the data, and it was found that the data was significant, and the UV filter chemicals did have direct results on the health of planarian. Therefore, the null hypothesis was rejected, along with the research hypothesis as the planarian exposed to avobenzone and octinoxate demonstrated had the lowest median ranking, which indicated the worst health on a scale from 1-4. The expected reason for the results was due to all the various chemicals proven to disrupt cellular behavior. For example, previous research demonstrated alterations in cell size, development, and biomass due to the chemicals.

Evelyn Ortuno - Finding a Buffer Solution to Protect Limestone from Acidic Rain
Washington-Liberty High School

The purpose of the study was to find out if a buffer solution would protect limestone from eroding, and if so, which one

would protect it the most. Two solutions tested were baking soda with a pH of 9 and an antacid with a pH 11. The control group was the limestone with no treatment. It was hypothesized that if a buffer is added, then the limestone would be less eroded than one without one because the alkaline solution would neutralize the acid rain. The null hypothesis was that the untreated limestone would react identically to limestone treated with buffer solution. 10 trials were conducted for each pH level and the control group. The study included 30 rocks with 10 coated in the two buffer solutions and 10 with nothing as the control group. The rocks were treated with solutions and then sprayed with a diluted vinegar solution mimicking acid rain. The experiment found baking soda protects the limestone the most regardless of if the antacid had a higher pH level.

James Paine -Testing the Efficacy of an Aquatic Aerator
Southwest Virginia Governor's School

When bodies of water, such as ponds, remain stagnant, their waters will begin to stratify, meaning they will separate into layers based on temperature, density, and oxygen content. This may contribute negatively to the pond's health. Aerators are used to remedy stratification by circulating the water and providing consistency and stability to the aquatic ecosystem. A neighborhood pond was connected via an underground pipe to Claytor Lake. An aerator was installed in hopes of improving its water quality. The aerator was deactivated, and subsequent measurements of dissolved oxygen and total nitrogen were taken at five designated sites for a five week period. The purpose of the experiment was to determine how effective the aerator was at improving the pond's water quality and if more provisions needed to be enacted. A dissolved oxygen sensor and kit were used to periodically evaluate changes over time. Total nitrogen concentration was determined through a calibration curve. Oxygen was analyzed through linear regressions and an ANOVA test, discovering a moderate to weak correlation relative to turning off the aerator. A significant $p = 0.0005$ suggested that Claytor Lake, the control, had less oxygen than the pond on average. A matched-pairs t-test was performed on nitrogen samples to determine a significant difference before and after aerator deactivation. With $p = 0.0049$, an increase in nitrogen was suggested; however, the change was not as prominent for Claytor Lake. In future experiments, more data and more precise equipment will be required.

Environmental & Earth Science D (HS ENV-D)

First Place

Oliver Wang – Low-cost Electrostatic Method for Efficient Cleanup of Oil
Thomas Jefferson High School for Science and Technology

Oil spills pose a large environmental threat; they are inevitable and not completely preventable. This is why most of the focus towards this problem is in the cleanup. Cleaning up oil spills is no easier than preventing them and is an ongoing problem revolving in our world. Many existing techniques in cleaning up oil spills are an issue and have many downfalls because they often tend to do more harm than good and many marine life are sensitive to the effects of these methods. Here, I introduce an effective and environmentally friendly method to clean up oil spills by taking advantage of the physical property of oil to pick up and hold static charge. I designed a circuit board and got my designed Printed Circuit Boards (PCB) manufactured and created a complete model which is easily scalable, safe, and gathers and captures the oil efficiently and quickly. It is able to completely separate the oil and the water wherever in the water column the oil spill may be in. I used my model to clean up a small-scale oil spill that I simulated. There is also no need for human interaction as I made the process of capturing and separating the oil automatic. This opens up more opportunities and methods to navigate oil spills and offers a more friendly, adaptive, and efficient cleanup of these spills. I am continuously advancing my research and currently designing a Remote-Controlled Boat that can navigate spills from a distance.

Second Place

Leila Silva -The Effect of Green Roofing on Solar-Cell Performance
Yorktown High School

As the threat of global warming increases, the development of clean energy becomes more of a necessity. Solar panels are becoming increasingly accessible, but their effectiveness is limited by their efficiency loss. While sunlight is necessary for solar cells to function, excess heat reduces their power output. One possible solution to this is green roofing, a type of roofing with a layer of vegetation. Through the process of evapotranspiration, the rooftop plants use the heat in the air to turn water into vapor, reducing surface and surrounding temperatures. It was hypothesized that due to these heat mitigation properties, installing a solar panel on a green roof would increase the panel's power output. To conduct the experiment, the power output in watts of an 11.6 x 11.6 cm solar panel was measured on a series of model roofs. A 150 W incandescent heat lamp was used as a proxy for the sun. The effects of green roofing were compared with two traditional roofing materials, EPDM rubber and asphalt. After testing, it was determined that the

hypothesis was supported by the data. Green roofing was found to have facilitated the highest average solar power output in respect to the other roof types. A one-way ANOVA test was conducted, and the P value was <0.001 , indicating that the data is statistically significant, and that the relationship tested is worth further consideration. However, more testing on a larger scale is needed to determine the exact extent to which green roofing increases solar-cell performance.

Third Place

Kennedy Puckett – Changes in *Pyrocystis fusiformis* Bioluminescence According to Light Intensity
Central Virginia Governor's School

The purpose of this study was to determine whether different intensities of light would affect the emittance of fluorescence of *Pyrocystis fusiformis*. The hypothesis was that if *Pyrocystis fusiformis* was placed under a UVB 10 bulb plus, the Daylight Compact Fluorescent Bulb, then the fluorescence percentage of these algae will be higher than the other groups tested. There were three groups used in this experiment: the control group, which was a Daylight Compact Fluorescent Bulb, the UVB 5 group that also had the control bulb, and the UVB 10 group with a control bulb added. Three, 250 mL beakers per group were tested for 14 days testing every Monday, Wednesday, and Friday. Fluorescence percentages for each group were calculated by using a Go Direct SpectroVis Plus Spectrophotometer; each beaker, for each group, was tested using this piece of equipment every day of testing. The groups were all set on the same circadian rhythm where they had a 12-hour light: dark cycle. A one-way ANOVA (alpha .05) determined that there was no significant difference with a p-value of .425, and the null was retained. Given that there was no significant difference, the research hypothesis was not supported, and the UVB 10 group did not show a higher percentage of fluorescence. The results suggest that *Pyrocystis fusiformis* will not be affected by a change in light intensity.

Honorable Mention

Brandon Thomason - Effects of Ecologically Relevant Concentrations of Microplastics on Photosynthetic Pigments of *Nannochloropsis microalgae*
Collegiate School

Microalgae are primary producers that are the foundation of the ecological pyramid. Marine microplastic pollution has had serious consequences on microalgae, causing damage to the cells. It has been shown that microplastics have decreased photosynthetic activity and cause the algae cells to display signs of metabolic stress, such as the release of extracellular polymeric substances. Looking at the concentrations of photosynthetic pigments of microalgae is a way to determine the damage caused by microplastic exposure, as the levels of photosynthetic pigments are directly related to the photosynthetic activity of a cell. This research examines the effects of different microplastic concentrations on

the microalgae genus *Nannochloropsis*. There is a gap in research about microplastic pollution, as much of the literature relating to the topic relates to the effects of microplastics or larger plastics on larger aquatic organisms. Nine 30 mL samples of *Nannochloropsis* algae with varying concentrations of microplastics were made and were grown for ten days under ideal conditions with Alga-Gro® Seawater Medium. Iron (III) chloride (FeCl_3) was then added as an inorganic flocculant to remove and separate the algae from the culture media. Once the culture media was removed, each culture was ground with acetone and magnesium carbonate to facilitate the extraction of photosynthetic pigments inside the cells by disrupting the cell walls. The acetone-pigment samples were analyzed spectrophotometrically, and the concentration of chlorophyll A and carotenoids were calculated. A one-way analysis of variance showed that there were significantly higher concentrations of both chlorophyll a and carotenoids in algae grown without microplastics than for algae grown with low concentrations or high concentrations of microplastics ($p = 0.003$). While there was not a significant difference in algae grown in a low microplastic environment and a high microplastic environment, this experiment still confirms previous findings and claims about the disruption of the internal photosynthetic pathways of microalgae. This result confirms previous research showing that microplastics increase metabolic stress and decrease the chlorophyll content of microalgae. Microplastic pollution is very serious and will cause damage to algae cells which in turn will cause unwanted harm to the rest of the biosphere. It is imperative that marine microplastic pollution is dramatically reduced to prevent further ecological damage. Future research on this topic can focus on additional ecological threats along with microplastics.

Honorable Mention

Frances Shapiro -The Effect of Type of Cover Crop on Water Runoff and Soil Erosion
Washington-Liberty High School

Water runoff and soil erosion in watersheds has caused increased pollution and led to the degradation of these bodies of water. The purpose of this study was to determine what type of cover crops would best reduce water runoff and soil erosion. The cover crops tested were tall fescue, annual ryegrass, and white clover. Bare soil was the control. It was hypothesized that the white clover would be the most effective in reducing water runoff and soil erosion due to its dense ground coverage and strong root system. The experiment was conducted by constructing an apparatus to simulate slanted ground over which runoff might occur. 250 mL of water were poured over each group and the average amount of runoff in mL was found after 6 hours. The results showed that the control group allowed for the least amount of water runoff, with 181.0 mL. Conversely, all three types of cover crops reduced soil erosion the most by allowing only 1.0 mL, while the control group produced 11.5 mL of erosion. The data collected suggests that all three cover crops are successful in reducing soil erosion and provides useful information for future ways to protect our watersheds from becoming polluted.

Honorable Mention

Caroline Smith - Effect of Chemical Fertilizers on the Biofertilizer Water Fern, Azolla: A Research Study on a Phosphorus-limited and Nitrogen-fixing Mutualism
Collegiate School

In the modern, industrialized world, chemical fertilizer runoff is a prominent pollutant in waterways. Infiltration of phosphorus and nitrogen into water systems can decrease dissolved oxygen concentrations, disrupting aquatic food chains. As individual algae accumulate fertilizer runoff, the excess nutrient introduction causes spikes in algae growth and proliferation of algae in large blooms. This type of runoff is an ongoing issue within aquaculture, especially in Asian rice paddies which utilize biofertilizing water ferns called Azolla. This aquatic plant has obligate cyanobacteria symbionts, *Anabaena*, in the folds of its leaves that fix nitrogen. Much like adding legumes to a terrestrial farm, when farmers add Azolla to their rice paddies, it serves as a living nitrogen fertilizer. Azolla is phosphorus-limited - its cyanobacteria need phosphorus inputs to fix nitrogen. However, when chemical fertilizers are introduced to water with biofertilizers, excess nitrogen and phosphorus have the potential to cause a bloom and mass die-off of Azolla that decreases dissolved oxygen with their decomposition. The present study examines effects of both a nitrogen-based fertilizer and a phosphate-based one on dissolved oxygen concentrations of Azolla aquacultures over 17 days. There are three treatment groups: control (no added fertilizer), nitrogen, and phosphorous. The control group's dissolved oxygen concentrations were significantly lower than both fertilizer-treated Azolla groups for day 5, 8, and 10 past a second fertilization. In addition, increases and decreases in dissolved oxygen levels were parallel over the course of the experiment with the phosphate and nitrogen groups having no significant difference from each other. The nitrogen group had the smallest negative percent change in dissolved oxygen, while the control group had the largest oxygen depletion when each group's oxygen levels were decreasing. These results largely demonstrate the dynamic between the Azolla and fertilizers in the plant's "bloom phase;" and had the experiment lasted longer, the fertilizer groups may have yielded larger die-offs and less dissolved oxygen. Similarly, the control group's dissolved oxygen concentrations may have always been lower because the fertilizers in the other two sample groups were promoting plant growth and photosynthesis that produced oxygen. Future studies should allow more time for data collection so that the Azolla has adequate time to absorb and react to fertilization.

Aarushi Rao -The Effect of Metallic and Biopolymer Coagulants on Microplastic Extraction in Water
Mills E. Godwin High School

Microplastics are a common pollutant which scientists have connected to the degradation of human health. Many impoverished regions cannot afford necessary water purification methods. Hence, the goal of this experiment was to determine if biopolymer coagulants, such as *Saccharum officinarum* (Sugar Cane), *Abelmoschus esculentus* (Okra), and *Dolichos lablab* (Hyacinth Bean), can remove similar amounts of microplastics comparable to those extracted by

the frequently employed coagulant aluminum sulfate (alum). For safety purposes, gloves/aprons were worn and food-grade, non-toxic alum was utilized. It was hypothesized that if metal coagulants are compared to biopolymer coagulants than the *Abelmoschus esculentus*, will extract roughly the same amounts of microplastics as the alum. One hundred milliliters of tap water and half of a gram of 0.1-millimeter silica beads were added into a cup, along with 0.2 grams of aluminum sulfate. The coagulant was mixed into the water for 30 seconds and after 2 hours, a 0.1 mm sieve was used to filter out any microplastic particles into a clean cup. This was repeated for all 25 trials of each independent variable level and the control level, which was the water introduced to no coagulant. The Okra extracted the most similar amounts of microplastics when compared to the alum. After performing ten t-tests, the data was shown to be significant at the 0.001 level. Okra likely performed the best because of the natural water-soluble polysaccharides found in Okra that destabilize colloidal suspensions, which can flocculate tiny particles and lessen turbulent drag, thereby clearing water turbidity. Further studies involve researching or blending new biopolymers for optimal microplastic extraction in developing countries.

Zahra Rizvi -Flowing into the Future: Addressing Urbanization's Impact on Water Quality in the Chesapeake Bay
Grafton High School

This project investigates the impact of urbanization on water quality in Chesapeake Bay, specifically in the Hampton Roads area. The null hypothesis for this study is that there is no significant relationship between Total Suspended Material (TSM) in the water and the two independent variables: population and percent urban or built-up land. A novel and inexpensive experimental setup is designed and developed to test the hypotheses. The experimental setup makes use of collecting Earth Observation (EO) data from Landsat 8 and Sentinel-2 satellites. To explore the potential water quality information that can be obtained from Landsat-8 imagery, ground truth water quality measurements were obtained from the Chesapeake Bay Data Hub. The EO data was used to perform analysis on the Google Colab environment using the Open Data Cube framework in Python programming language. Each land pixel of the EO raster data is marked based on its urban or built-up land use. Additionally, a renowned algorithm is used to calculate the TSM value for each water pixel from the EO data, which is a good proxy to monitor water turbidity. The yearly population data is obtained from the United States Census Bureau. This study uses multiple linear regression analysis to examine the relationship between the variables. The data used in this analysis covers a period of five years and is collected from seven cities in the Hampton Roads area near Chesapeake Bay. The results of the regression analysis indicate that the model is significant and fits the data well, with an R-squared value of 0.7999 and an adjusted R-squared value of 0.7995. The coefficient estimates for the independent variables provide insight into how they affect the dependent variable. The coefficient for the "Population" variable (0.0399) indicates that for every additional unit of population, the TSM in the water increases by 0.0399 mg/L, all else being equal. Similarly, the coefficient for the "Percent Urban or Built-up Land" variable (3836.0964) suggests that for every one percentage point increase in the amount of urban or built-up land, the TSM in the water increases by 3836.0964 mg/L, all else being equal. Finally, the coefficient for the

interaction term "Population \times Percent Urban or Built-up Land" (-0.0028) indicates that the effect of population on TSM is modified by the percentage of urban or built-up land in the area. It's important to note that although the model is significant, it does not necessarily imply causation. Other factors that are not included in the model may also be influencing the TSM in the water. Therefore, the results of this study should be interpreted with caution and considered in the context of other research and knowledge of the system being studied. The research findings can be useful to environmental engineers and management professionals by informing the development of effective management strategies, implementing monitoring programs, supporting policy development, and promoting sustainable development practices. The study identifies the key factors contributing to water quality degradation in the Chesapeake Bay region and provides scientific evidence to inform policy making and ensure future development is sustainable.

Madeleine Roncka -The Effect of the Type of Water on the Turbidity
Yorktown High School

Many different factors can affect the turbidity of water. This experiment was conducted to observe the environmental impacts of pollution on turbidity within a local water system. By testing the turbidity of water samples from different local bodies of water, it can be discovered how the water in Arlington Virginia is polluted. The experiment was designed to find which streams in Arlington Virginia had the highest turbidity. There was a definite conclusion to the experiment: if the types of water were changed, the turbidity of the water could vary based on location. The data from the trials express a significant increase in turbidity as the water sample location changes. The location with the samples of the highest turbidity has the most total suspended solids, or TSS. TSS can be a visual indicator of water quality as well if the concentration is high enough. The average data showed that Windy Run Park had the highest ppm, of 270.4. There were two analytical tests run on the experimental data: a post-hoc test and an ANOVA (analysis of variance) test. The test results demonstrate that the experiment is repeatable. The tests conducted also proved the hypothesis of the experiment to be correct.

Lucas Royster -The Effect of Organic Pesticides on the Ladybug *Hippodamia convergens*
Mills E. Godwin High School

The purpose of this experiment is to determine how organic pesticides affect helpful insects such as ladybugs compared to synthetic pesticides. The best way to get rid of harmful insects in yards and farms is by using pesticides, but most pesticides are created in a lab and can kill helpful insects as well as harmful insects. This could create an ecosystem imbalance and certain organisms that are normally kept in check by helpful insects would run wild and destroy crops. This would end in a loss of income and destruction of the environment. Organic pesticides that come from nature instead of a lab may be less harmful to helpful insects that may be caught in the crossfire than the synthetic

pesticides that kill everything in their path. Fifty ladybugs were exposed to the synthetic pesticide permethrin; and the organic pesticides garlic oil, peppermint oil, and neem oil. The ladybugs were left for an hour and the number of ladybugs that had died was counted. Distilled water was used as a control. It was hypothesized that the synthetic pesticide permethrin would kill more ladybugs than the organic pesticides garlic oil, peppermint oil, and neem oil. The results showed that permethrin killed 46 ladybugs compared to garlic oil, peppermint oil, and neem oil's; 12, 16, and 25. An χ^2 test was performed and showed the data was significant for permethrin vs expected, garlic oil vs expected, and distilled water vs expected but not significant for peppermint oil vs expected, and neem oil vs expected. The results did support the research hypothesis.

Alina Sagatov – What Time Period Creates the Most Amount of Biofuel in the Least Amount of Time
Washington-Liberty High School

Biofuel is a fuel that is derived directly from living matter, algae is a very common source of biofuel. The purpose of this study was to determine the most effective growing time for algae to be produced. The growing times for algae were 3 days, 6 days, 9 days, and 12 days. After the algae was harvested it was then produced into biofuel. It was hypothesized, If algae were grown in different amounts of time, then those grown within days 6-9 will grow the most because algae thrives in an environment that has enough nutrients and space for it to grow while not being too crowded. The results showed that the most amount of biofuel was created on day 12 as expected, the However, the algae had diminishing returns from days 6-12. The data suggests that algae grown in 6 days was the most effective at producing the most amount of biofuel. The data collectively suggests that all days produced biofuel that can help change the world, the project provides further insight into the best strategies for various purposes.

Srinidhi Subramanian -The Effect of Differing Water Sources on the Efficiency of TSP Flocculant
Mills E. Godwin High School

The purpose of this experiment was to determine whether Tamarind Seed Polysaccharide (TSP) powder could be used as an alternative to chemical flocculants such as Polyacrylamide for microplastics in various water sources. The hypothesis was that if the extract was used in freshwater, the microplastics would flocculate the best because freshwater provides the most optimal conditions for plant-based polysaccharides to work. Chemical flocculants like Polyacrylamide are both harmful for the environment and toxic once they break down. Plastic pollution is a key concern to both the environment and public health, but chemical flocculants do more harm than good towards solving the problem. Therefore, research has turned towards plant-based solutions. This experiment added TSP to freshwater, marine water, bottled water, and tap water, that contained polyethylene microplastic spheres. The samples were observed for 30 minutes to determine the efficiency of TSP powder in clumping microplastics together. The diameter

of the clumps was measured before and after the experiment and the change in diameter was calculated (mm). The results revealed that the TSP powder worked the best in fresh water and worst in tap water. The freshwater data yielded the highest average and significant results, while the tap water yielded the smallest average and insignificant results, supporting the research hypothesis. Freshwater worked the best due to its pH range of 6-8 which is optimal for coagulation, the main property that makes TSP an effective alternative. Tap water did not work as well since its pH range exceeds eight.

Julissa Valdez - Comparing Detergents Impacts on Brine Shrimp Hatching and Survival
Chesapeake Bay Governor's School

The water system's health has been deteriorating since the surplus of contaminated organic pollution due to surfactants found inside streams of water. Detergents, petroleum, and cleaners are standard household products that have contributed to the increase of toxic chemicals because of the number of products used daily. Companies have been trying to fight this issue by creating safer green formulations for the environment and people. However, little research has been done to determine if these products are a safer alternative or if they do more harm than good. This study's purpose is to test two alternative green soaps and one conventional soap to determine which soap is safer and if there are any after-effects due to the soaps. The hatch rate and mobility of brine shrimp were measured to determine this. One conventional soap (Dawn), two eco-friendly soaps (Seventh Generation and ECOS), and the control group comprise four groups. To determine the hatch rate (alive/dead x 100), 100 items (hatched shrimp and eggs) were collected after five days. The shrimp were then observed to determine whether they belonged in the hatched eggs' low mobility, moderate mobility, or high mobility groups. The results were significant to reject the null hypothesis. Even if eco-friendly detergents do not kill animals, this study found that they may still have adverse effects and are safer than conventional soap. In a short amount of time, this study provided additional evidence of the impact of green alternatives on aquatic life. Compared to Dawn, using soaps like Seventh Generation may have a shorter-term negative impact on water systems. Additionally, this study demonstrated the significance of researching green-formulated products and the fraudulent marketing of those products. This raises awareness of large corporations attempting to join the eco-friendly trend.

Jack Wilder - Testing the Public's Knowledge About Commonly Foraged Mushrooms
Southwest Virginia Governor's School

In the United States, 7428 cases of mushroom poisoning are reported annually, most of which are caused by lack of information or misidentifying a mushroom. There are many lookalikes in the mushroom kingdom, and while there is information available regarding how to distinguish these lookalikes, many people do not heed this information. The

objective of this experiment was to determine whether information on a group of mushrooms commonly referred to as the “Foolproof Four” and their lookalikes is effective in helping people identify mushrooms. Those mushrooms include the morel (*Morchella esculenta*), the puffball (*Calvatia gigantea*), and the jack o’lantern mushroom (*Omphalotus olearius*). To test this question, twenty-six participants were given the same survey before and after receiving information about the content of the survey, which consisted of four of the most commonly foraged mushrooms and their lookalikes. A matched-pairs test was used to interpret the results. Since the P-value < 0.05, the null hypothesis was rejected and the alternative hypothesis was accepted. It was found that participants scored higher after they read the information 84.62% of the time. The mean score pre-information was 32.42%, while the mean score post-information was 66.48%. These results suggest that in-depth information about mushrooms could be useful to inform people about what they should look for before they go foraging.

Emaad Zakriya -The Effect of Various Particle Pollutants and Organic Air Filters on the Efficiency of a Photovoltaic Cell
Mountain View High School

Throughout the world, air pollution is found largely within countries that are less developed, like China and India. They are also some of the world’s largest users of solar energy. Research has shown as well that the air pollutants in these countries have had negative effects on the generation of solar energy through solar panels. Thus, the research objective was to discover the effect various organic air filters had on the concentration of particle pollutants present in the air, and how those air pollutants would affect solar panel efficiency. This was done by using a dosimeter, which is a machine that can say how much UV radiation is hitting a sensor, to check the amount of UV radiation hitting it from a UV flashlight through a cloud of the pollutant and then checking the amount of UV radiation that was hitting it after the pollutant was filtered out. The percent change was then calculated between these two values, giving the data points. Once the percent change was found for each variable over five trials, the data was put into a two-way ANOVA test, and it was found that at least one of the air filters had an effect on the amount of UV light that hit the dosimeter, at least one of the pollutants had an effect on the amount of UV light going through the box, and the interaction between the two variables was significant, meaning the two variables together had an effect on the amount of UV light that was reaching the dosimeter. To find out which of the variables were statistically significant, a paired t-test was performed. This test found that there was a significant difference between the air filters when filtering dust, and the best one is the carbon filter. It also showed that there was no significant difference between the air filters when filtering soot and pollen, so any air filter should be the same, meaning the null hypotheses can be rejected, and the alternative hypotheses can be accepted. The experiment proved that some pollutants do have an effect on the amount of UV light that goes through to the photovoltaic cell and can save lives and the money of many.

Sofia Ziegler -The Effect of Artificial Turf Field Usage on Particulate Matter in the Air
Central Virginia Governor's School

The purpose of this study was to determine whether usage of an artificial turf field affects the concentrations of particulate matter in the air. This study was conducted at a local university's indoor artificial field in November and December of 2022. The hypothesis stated that after an hour of being played on by a group of children, the PM_{2.5} and PM₁₀ concentrations (in micrograms per cubic meter) in the air above the field would increase. The data was collected at three different points on a field before and after these periods of use using a Temtop LKC100S+ air quality index monitor. The mean for PM_{2.5} before was 1.15 ug/m³, PM_{2.5} after was 1.46 ug/m³, PM₁₀ before was 2.00 ug/m³, and PM₁₀ after was 2.56 ug/m³. The data was analyzed using two paired t-tests with an alpha of .05, and the p-value for PM_{2.5} was 2.00×10^{-05} and for PM₁₀ was 1.91×10^{-05} . This showed that the data was statistically significant and supported the research hypothesis that activity on the field would increase the air particulate matter.

Mathematics: Theoretical & Modeling (HS MTM)

First Place

Mathematics Award

Phillip Naveen - FASFA: A Novel Next-Generation Backpropagation Optimizer

Mills E. Godwin High School

This paper introduces the fast adaptive stochastic function accelerator (FASFA) for gradient-based optimization of stochastic objective functions. It works based on Nesterov-enhanced first and second moment estimates. The method is simple and effective during implementation because it has intuitive/familiar hyperparameterization. The training dynamics can be progressive or conservative depending on the decay rate sum. It works well with a low learning rate and mini batch size. Experiments and statistics showed convincing evidence that FASFA could be an ideal candidate for optimizing stochastic objective functions, particularly those generated by multilayer perceptrons with convolution and dropout layers. In addition, the convergence properties and regret bound provide results aligning with the online convex optimization framework. FASFAGrad and FASFA+ diversify the optimizer into two distinct lineages for selective and ultra-selective hypotheses. In a first of its kind, FASFA addresses the growing need for diverse optimizers by providing next-generation training dynamics for artificial intelligence algorithms. Future experiments could modify FASFA using bandit-based multi-start strategy.

Second Place

Anooshka Pendyal - Optimizing Quantum Annealing to Advance Graph Coloring Algorithms

Deep Run High School

Quantum computing is a rapidly growing field that applies quantum mechanics to computer science and its algorithms, and it has many applications, including optimization problems, where the goal is to obtain an optimal solution to a multivariable problem. Quadratic unconstrained binary optimization problems can represent combinatorial optimization problems, which have a wide range of applications from artificial intelligence to finance. Thus, Sudoku problems, which can be classified as graph-coloring problems, can be represented as optimization problems so that they can be solved with quantum annealing, the process of using quantum fluctuations to solve optimization problems. This project aimed to use Sudoku as a method of evaluating the performance of the latest quantum annealer and to develop a novel method to reduce the number of variables in a QUBO formulation representing Sudoku problems. Creating a more efficient formulation has applications in artificial intelligence and data mining. First, the Sudoku problem was formulated

as an objective function so that it could be converted into a QUBO formulation, and the variables could be reduced. Then, test cases of various difficulties were created, and each was solved with both quantum annealing and simulated annealing. The experiment showed that both quantum annealing and simulated annealing can be used to effectively solve Sudoku problems, although they do have limitations when the number of missing digits from the puzzle exceeds a certain amount. The variable reduction technique was also proven to be effective as it reduced 85 to 99% of variables in all test cases.

Third Place

Zachary Schwehr - Brain Tumor Segmentation and Classification Based on Deep Learning, Attention Mechanisms, and Energy-Based Uncertainty Predictions
Mills E. Godwin High School

A brain tumor is a foreign growth within the brain that disrupts function. Brain tumors are one of the deadliest forms of cancer with a mortality of 80%. As a result, a quick and accurate diagnosis is crucial for survival. Typically, brain tumors are diagnosed through a series of MRIs and biopsies that are manually annotated by neuroradiologists and other specialized physicians. These evaluations are costly, time-consuming, and have high degrees of error due to their complexity. To aid in this process, various models were proposed for brain tumor and glioma classification, region of interest detection, multi-class segmentation, and uncertainty estimations. The classification models achieved state-of-the-art results when classifying gliomas, meningiomas, pituitary tumors, astrocytomas, glioblastomas, and oligodendrogliomas by outperforming its contemporaries. The proposed convolutional neural networks (CNNs) implemented strided convolutions, batch normalization, and hyperparameter bayesian optimization to decrease data loss and find ideal hyperparameters. These models classified brain tumors and gliomas with an accuracy of 98.4% and 99.05%, respectively. The segmentation model achieved state-of-the-art results with dice scores of 89.6, 89.2, and 85.5 for the peritumoral edema, non-enhancing tumor core, and enhancing tumor regions on the BraTS 2020 dataset. Due to potential noise and the imperfection of the model, an energy-based model (EBM) was used for voxel-based uncertainty. Using the uncertainty estimation of each voxel, physicians can trust the tumor regions where the model is confident and ignore the uncertain areas. Overall, the proposed models significantly outperformed previous works and expedites brain tumor diagnosis.

Honorable Mention

Hannah Qi - Diagnosis of Melanoma Skin Cancer Using Convolutional Neural Networks
Central Virginia Governor's School

The purpose of this study was to determine whether developing a deep learning algorithm trained to identify melanoma

and benign skin cancers will be effective in the diagnosis of skin cancers. A convolutional neural network (CNN) is a specific type of deep learning algorithm that recognizes patterns and categorizes images, so it was natural to use CNNs in this study. This study successfully developed three different CNNs that were applied to an unlabeled dataset consisting of images of benign and melanoma cancer lesions. The number of convolutional filters was adjusted for each model so that there were a few, moderate, or large number of filters, producing accuracies of 68.421%, 89.474%, and 57.897% respectively. A one-way ANOVA was run on the prediction accuracies. The data was statistically significant since the F-statistic value of 65535 was more extreme than the F-critical value of 5.143. Following the one-way ANOVA, a post-hoc Tukey test was run with an alpha value of .05, and it determined that there were significant differences between all three groups as the differences in the averages all exceeded the Dmin value. The statistically significant results supported the research hypothesis, which stated that the CNN with a moderate number of filters would produce the highest accuracy. Therefore, applying the principles of this experiment to the medical field bridges the gap between the capabilities of humans and machines and will be very beneficial in improving the accessibility, reducing the cost, and minimizing the invasiveness of the diagnosis of skin cancer.

Honorable Mention

Ayush Pal -The Effect of Genetic Sequence Vectorization Methods on the Accuracy of Promoter Sequence Classification using NLP Techniques
Mills E. Godwin High School

Machine learning is a method of data analysis that automates analytical model building; it is based on the idea that systems can learn from data, identify patterns, and make decisions with minimal human intervention (SAS, 2022). Recently, machine learning methods have been applied to fields in biology and medicine to produce cancer detection and diagnosis algorithms and have shown cutting-edge results. However, one application yet to be deeply explored is the analysis of genetic sequences using intelligent algorithms. One approach to this problem entails the usage of natural language processing (NLP) techniques and the analogization of DNA to language. NLP involves converting language into a numerical form, through vectorization and encoding processes, for calculations to be performed. Many vectorization methods have been developed and proposed for specific applications, so the goal of this study was to determine an optimal technique for vectorizing and encoding DNA sequences while preserving their hidden information. The benchmark problem used in this study was the classification of promoter sequence strength. A promoter is a short region of DNA (100-1,000 bp) where transcription of a gene by RNA polymerase begins (Khanh Le et al., 2019). It controls when and how much to express the gene, also known as its strength. It was hypothesized that FastText embedding would be the most optimal, which indeed achieved the highest accuracy of 97%. Not only is it successful in promoter sequence classification, but this vectorization method can also be applied to all other implementations of NLP in genetic sequence analysis.

Honorable Mention

Venkata Naga Sai Kaushik Yadala - Modeling the Eradication and Spread of Poliomyelitis in Relation to Hesitancy in Vaccine Acceptance

Central Virginia Governor's School

The purpose of the study was to create a reliable mathematical model that models the spread of poliomyelitis (polio) in relation to the polio vaccine, immunization efforts, and vaccine hesitancy among people. Data regarding polio infections were collected from databases like the World Health Organization. The data was used to build a reliable mathematical model that models the spread of polio using a modeling software called I See Systems Stella. The model created was inconclusive because of the unpredictable behavior of the population in the mathematical model. There was no proper data to support or not support the research hypothesis. In summation, the spread of polio was not modeled correctly as shown by the inconclusive results.

Devesh Kumar - Coolidge: A Novel Regularization Method to Revolutionize Neural Networks

Maggie L. Walker Governor's School

This research aimed to develop the most effective image recognition neural network model. A neural network, which consists of a system of nodes that store a value, is trained repeatedly through backpropagation calculus and gradient descent. Sometimes, this network can become overly complicated and ineffective. A residual neural network can resolve the vanishing gradient problem when weights become too small through skip connections in a very deep neural network. Regularization, a technique where weights are minimized to simplify the model, can help ensure that the model is concise. While it was clear a residual neural network would be effective, it was unclear what kind of regularization technique should be used. L1 regularization, which minimizes the sum of the absolute values of all the weights in the model, and L2 regularization, which minimizes the sum of the squares of all the weights in the model, are known techniques. However, a new technique, called Coolidge regularization, was invented by the researcher to combine these two methods by finding the arithmetic mean of the L1 and L2 weights multiplied by a constant. By running all three methods through a neural network model with repeated trials, it was discovered that the Coolidge regularization was the most effective since it had the highest average test accuracy on a set of images being classified. This has enormous implications for society: neural networks can be more accurate, therefore image recognition as a whole will be more accurate. From facial recognition to autonomous vehicles, society can be improved. Moreover, this research can be a branching off point for future improvements to neural networks. The more accurate these models get, the more reliable their results are, and the more technology can grow. This research provides a new innovation to the AI community so that the industry can move forward into the future.

Oscar Montgomery - Effects of School Size on Cross Country Runners' Speed
Southwest Virginia Governor's School

In the research the goal was to determine if there is a correlation between the size of schools and the performance of their cross country teams. This research was important because in the ever changing field of athletics having current data can help a coach to form a team that will have better chances at winning races. The problem this research was looking into was to see if there is an unfair advantage of larger schools over smaller schools. The primary sources of data were the Virginia High School League(VHSL) website and the Virginia Milestat website. These sources were chosen because they will provide current and reliable data. The times all came from the region meets of teams and the student populations were gathered from the VHSL website. Whether the schools had teams was another data point examined. The data provided a look into how the student population size affects the school's cross country team performance. In the end, because the slope has an approximate decrease in times run by boys cross country teams of $-2E-05$ when we increase the student population by one student, and because the slope has an approximate decrease in times run by girls cross country teams of $-3E-05$ when we increase the student population by one student, as well as the r values for both boys and girls teams, it can be said that there is a weak, negative, linear association between school population and the times cross country teams ran. These results show that based on the data the alternate hypothesis can be rejected, and we fail to reject the null hypothesis. These results are a good sign that, even with the size difference, small schools can still compete with larger schools.

Davis Reitzel - Exploring Collatz Conjecture
Southwest Virginia Governor's School

Collatz Conjecture was created in the 1930s by Lothar Collatz and has perplexed mathematicians for almost a century. The Collatz problem is an iteration of $n/2$, when n is even, and $3n+1$, when n is odd. The Collatz Conjecture states that all natural numbers will reach the value one as it goes through the iteration. Terry Tao made a breakthrough discovery on the problem using a statistical weighting method to show that almost all numbers reach one; however, he did not prove it. An integer that increases for infinity in the iteration will disprove this conjecture. By maintaining an even, odd pattern in the iteration, a number will increase to infinity. The purpose of this research was to find a way to maintain an even, odd pattern by analyzing the unit digits of an integer's sequence. An ANOVA was done to analyze the average sequence length for integers that ended with each unit digit. The results were that the unit digit did not affect the sequence length. After analyzing multiple sequences, a method was found to extend a number's even, odd pattern. By repeating this method on a number, the even, odd pattern will continue to increase for infinity; however, a finite number that disproves Collatz Conjecture is never found. This research failed at disproving Collatz Conjecture, but a way to control the numbers in the sequence was found. These findings could influence the works of future mathematicians that attempt to solve this problem.

Abhinav Tadinada - Optimization of Distance Heuristics for Use in a Conflict-Based Search Path-Finding Algorithm
Mills E. Godwin High School

The purpose of this study is to determine if different distance heuristics have an effect on the performance of the Conflict-Based Search (CBS) path-finding algorithm. The CBS algorithm has quickly become one of the most common algorithms used in path finding; however, the basis of the algorithm uses heuristics to evaluate the value of going to a new position. There are different heuristics, and some may perform better than others. It was hypothesized that if the Conflict-Based Search algorithm utilizes a Manhattan Distance heuristic, the agents will be able to find shorter paths with fewer conflicts. A CBS algorithm was sourced from GitHub, and it was modified to fit the needs of this study. Then, 3 different environments were created, and the different heuristics were tested in each environment. The path length and number of conflicts was recorded and compared. Overall, the data was statistically insignificant with the exception of two t-tests which both involved the Manhattan heuristic. In both tests, the Manhattan heuristic produced significantly shorter paths which means the research hypothesis is supported. These results can be explained by a phenomenon known as the “Curse of Dimensionality” where some heuristics are unable to perform properly at high dimensions due to a change in ratios. This phenomenon affects Euclidian distance more than it affect Manhattan distance which explains why Manhattan performs better at the high level. For further study, a neural network should be implemented into the code to allow it to function as a machine learning model. This would provide more efficient paths and allow the algorithm to learn from its experiences. Additionally, the dimensional effect on heuristics could be studied to determine why the change in ratio affects heuristics.

Medicine & Health A (HS MDH-A)

First Place

Vidya Ambati - Haloperidol inhibits Inflammasome Activation and Reduces the Risk of Rheumatoid Arthritis
Albemarle High School

Rheumatoid arthritis (RA) is an autoimmune joint disease that affects nearly 1% of people worldwide. RA disproportionately affects women, indigenous peoples, and those of lower socioeconomic status, and it results in an estimated \$70 billion annual medical and economic burden. Tissue damage and destruction in this chronic, inflammatory condition results from interactions between immune cells and synovial fibroblasts. There is no FDA-approved therapy for preventing RA, which causes disability, reduced quality of life, and increased mortality. I performed an unbiased global scan of all 4,302 FDA-approved drugs and identified a significant association between reduced development of RA and the use of haloperidol (Haldol), which is used to treat certain mental disorders. I validated this link by analyzing 3 diverse nationwide health insurance databases of over 200 million people using Cox proportional hazards regression and Kaplan Meier survival analyses as well as random effects meta-analysis. I identified a dramatic and significant reduction in the risk of developing RA among people with mental disorders who were treated with Haldol compared to those treated with other anti-psychotics. Mechanistic studies revealed that Haldol also inhibited two important inflammatory cytokines – interleukins IL-1 β and IL-6 – in human macrophages and human synovial fibroblasts, two critical cell types in the development of RA pathology. Furthermore, Haldol inhibited inflammasome activation, as measured by ASC speck formation and caspase-1 cleavage, in human macrophages. Using affinity probe-mass spectrometry, I identified a novel interaction between Haldol and the lysosomal protein LAMTOR1. Haldol inhibited LAMTOR1 chaperoning of inflammasome assembly, identifying a novel mechanism of action. Collectively, these studies identify Haldol as a potential drug repurposing candidate that could become the first preventive therapy for a major unmet medical need that causes disability in millions of people in the United States and across the world.

Second Place

Mercy Akanmu - Differences in the Physical and Structural changes during Microglial Activation in Pediatric and Adult Glioma models.
Blacksburg High School

Gliomas are a deadly form of brain cancer. Methods of treating gliomas are failing to induce major changes in living

quality and life expectancy in those afflicted. While this type of cancer has different classifications and grades of severity that affect individuals in different ways, the prognosis is usually fatal. This incapacity to provide care expands across both pediatric and adult populations, leading to fatalities annually. Studies have examined the body's natural response to malignant cell growth, including the immune response of microglia cells. However, there are scarce studies relating to variance in response to gliomas in pediatric and adult gliomas. This paper investigates the differences between the activation of microglia cells (microgliosis) in response to gliomas and the average count of the microglia cells in adult and pediatric populations. Tissue was stained using the Avidin Biotin Complex Method (ABC) method, and images were analyzed using ImageJ. This study found a mean fluorescence of 21.444 and a mean cell count of 66.5 in the pediatric glioma population. The adult glioma population had a mean fluorescence of 15.290 and a mean cell count of 57.6. These findings suggest a higher microglia cell count and activation rate in pediatric patients compared to adults.

Third Place

Olivia Bartrum - Analysis of Anti-Inflammatory Compounds in Drug Absorption and Calculated Transdermal Permeability Utilizing the Parallel Artificial Membrane Permeability Assay
Wakefield High School

Determining transdermal permeability of compounds facilitates an understanding of drug distribution, improving quality of medical care. The study's purpose was to analyze transdermal drug absorption of anti-inflammatory compounds at varying concentrations. The parallel artificial membrane permeability assay provided an in-vitro model for simulating passive transdermal absorption via a dodecane and polyvinylidene fluoride membrane. Due to its smaller particle size, capsaicin was hypothesized to be more permeable relative to hydrocortisone and menthol. It was also hypothesized that a direct relationship between drug concentration and permeability would exist. Serial dilutions were undergone for each compound to create the desired concentrations (1mM, 0.1mM, 0.01mM, 1 μ M). Each compound and its associated concentration were transferred to the assay's donor plate (n=3). Blank controls were added separately to account for the presence of DMSO and PBS. Following incubation, UV-Vis spectrophotometry analysis was performed. Capsaicin had the highest UV absorbance at all concentrations. Two-factor ANOVA testing with replication revealed a statistically significant difference in UV absorbance between compounds (1mM: $p=1.40E-17$, 0.1mM: $p=2.31E-26$, 0.01mM: $p=4.47E-11$, 1 μ M: $p=4.89E-23$). UV absorbance values were utilized to calculate permeability rate. At 1mM, hydrocortisone (4.84E-5 cm/s) and menthol (8.08E-6 cm/s) experienced a higher permeability rate than capsaicin (6.61E-6 cm/s), refuting the hypothesis. This relationship was noted at all concentrations, implying a direct relationship between particle size and transdermal permeability. Increased concentrations were generally associated with concurrent increases in permeability rate, supporting the initial hypothesis.

Honorable Mention

Rockwell Li - Swim Smart, Swim Fast: Development and application of a Fitbit app for Swim Technique Study
Ocean Lakes High School

Swimming is a highly technical sport. Knowing what stroke technique to use and to what extent it should be used is crucial to having a better time. For example, in breaststroke, the stroke rate of the stroke is not the higher the better. The research question for breaststroke is: what is the effect of stroke rate on heart rate? In freestyle there are also certain techniques such as strike speed and stroke type (hip driven and shoulder driven which I will explain in the presentation). For freestyle the research questions are: what is the effect of strike speed on distance per stroke and what is the effect of shoulder driven and hip driven strokes on heart rate? My hypothesis for breaststroke is that the higher the stroke rate, the higher the heart rate. My hypothesis for freestyle is the lower the strike speed, the higher the distance per stroke and that shoulder driven strokes will have a higher heart rate. There are many ways to gather quantitative data when I swim. Some of them use whole Utilizing a fitbit versa 3 to track heart rate and acceleration of certain parts of the body. In order to use the fitbit versa 3 to gather data, an app is needed to save and send the data. We also used data analysis on data extracted from the fitbit to count the total number of strokes per 25.

Honorable Mention

Stan Craig - Effect of Speech Targets Used by Stutterers to Achieve Fluency on the Reactions of Non-Stutterers
Collegiate School

Stuttering is a common condition that affects about 60 million people worldwide. While outside the full command of expressive language, these individuals are usually no different from fluent speakers, they still face a unique set of challenges in their life with their stutter. Through therapy programs, such as the one offered by the Hollins Communications and Research Institute (HCRI), stutterers can learn and adopt methods to achieve fluency. A major component of HCRI's intervention is to provide highly specialized language treatment to effectuate changes in clients' speech patterns that result in fluency. During treatment, speech targets are taught to provide clients with alternative structures for the production of their speech. In this study, human participants listened to three audio samples, each of which was a reading of an identical passage, spoken by an HCRI clinician. In each audio sample, the clinician utilized a different speech target: first stretched syllable, second amplitude contour, and third no target. After hearing each of the three samples, the participants responded to four prompts that attempted to determine the participants' perceptions of the speaker and their speech. In order to reduce bias, the participants were told that the samples they heard were randomized and that they could all be the same, two be the same, or all be different, and the participants were also only given 10 seconds after each sample to respond to the prompts to make their answers instinctual and reactionary. A trend was found in which for each sample, the average scores of the responses to the sample with no target were higher than the average scores of the responses to the sample with a stretched syllable target which were, in turn,

higher than the average scores of the responses to the sample with an amplitude contour target. However, when analyzing the standard errors of the average answers, 8 out of 12 of the standard errors overlapped with each other, which indicates that the trend is not as clear as it may seem. Ultimately, the null hypothesis was rejected, but there are caveats to this conclusion. Even though the trend of the rankings of the average scores is apparent, the standard errors show that this study cannot be entirely conclusive. This study shows that speech that is different from speech without the application of targets is not necessarily looked at unfavorably and that people are still accepting of the different ways individuals construct speech patterns. Services and opportunities to gain fluency are available, like at HCRI, and the path to fluency is achievable.

Honorable Mention

Nitya Kumar - The Effect of Different Concentrations of liquid Melatonin on the heart rate of *Daphnia magna*
Douglas Southall Freeman High School

Melatonin is a hormone that regulates aspects like sleep rhythms, blood pressure, and immune function. Though melatonin is a commonly used supplement, the effects of melatonin, especially its effect on the cardiovascular system has not been well studied. *Daphnia magna* are tiny planktonic crustaceans and are common organisms used to perform experiments, especially relating to the heart rate.

The purpose of the experiment was to study the effects of liquid melatonin on the heart rate of the *Daphnia magna*. The hypothesis was: "If the *Daphnia magna* is exposed to the different concentrations of liquid melatonin, then the heart rate of the *Daphnia magna* would decrease." The different concentrations of 10 mg/mL liquid melatonin were 1:1 dilution, 1:5 dilution, and 1:10 dilution. Five trials for each concentration were conducted. The number of heartbeats was recorded in a data table and multiplied by four to get the number of heart beats per minute (bpm). Statistical analysis was conducted using the measures of central tendency as well as a two tailed t-test. The average heart rate of the control group was 220 bpm, and the average heart rate of the 1:1 dilution was 172 bpm. For 1:1 dilution, the t-value was 26.83. The P value was <.00001. The statistical analysis was also significant for 1:5 and 1:10 dilution. The heart rate of the *Daphnia magna* decreased significantly when exposed to the different concentration of melatonin which supported the experimenter's hypothesis. Melatonin supplement has been shown to help as a sleep aid as well as managing stress and anxiety. The effect of melatonin is most likely linked to its effect on reducing the heart rate.

James Brown - Correlation of Different Exercises to Performance Level in Rock Climbing
Central Virginia Governor's School

The purpose of this study was to determine whether or not various measures (pull-ups, weighted pull-ups, weighted

dead hang, unweighted dead hang, front lever, bench press, back squat, experience, and frequency) correlated with climbing ability, which was separated into two disciplines: boulder and sport climbing. A survey was sent out to several nearby climbing gyms and posted online to gather responses in which participants listed their climbing level and ability to perform several exercises. A regression analysis of the 15 responses was run against an alpha value of .05. The results showed a significant ($p < .05$) correlation between pull-ups and boulder, pull-ups and sport climbing, weighted pull-ups and sport climbing, and front lever and sport climbing, while all other relationships were insignificant. The research hypothesis, stating that the finger strength exercises (weighted and unweighted dead hangs), would have a significantly greater correlation than any other measures to both climbing disciplines, was not supported, as the finger strength exercises were found to have an insignificant relationship with climbing ability. This study suggested partial significance between certain exercises and climbing.

Nathan Cairns -The Effect of Material Color and Type of Material on Amount of UV Radiation Blocked
Clover Hill High School

Many people are educated on cancers such as lung and breast cancer, but one that is easily forgotten about and many overlook is skin cancer. Skin cancer is extremely dangerous, but the effects can easily be lessened or even prevented by wearing the right clothing. This experiment aimed to discover what that right clothing is through testing different materials and dyes. The hypothesis was that the more cotton was in the shirt, the more ultraviolet light would be blocked, and the darker the color of the shirt, the more ultraviolet light would be blocked. To test this hypothesis, 18 unique t-shirts were taken outside, and the amount of ultraviolet light blocked was measured using an ultraviolet light meter above and below a layer of the fabric. Overall, the results suggest that the data was significant, and that the opposing hypothesis was correct, which stated more ultraviolet light was blocked when there were lighter colors and less cotton. After collecting the data, the null hypothesis was rejected, demonstrating certain fabrics have an effect on exposure to ultraviolet light and radiation.

Milania Dehring & Krish Seth - *Dugesia dorotocephala* as a Novel Animal Model to Replicate Abstinence-related Withdrawal Symptoms after Prenatal Nicotine Exposure in Neonates
Governor's School @ Innovation Park

Neonates exposed prenatally to addictive substances (e.g. nicotine, opioids, etc.) experience withdrawal signs collectively known as neonatal abstinence syndrome (NAS). The number of neonates born with NAS has increased heavily (82% from 2010 to 2017, nationally) and placed an increasing burden on the healthcare system (\$462 million in hospital costs for Medicare financed births in 2014). Animal models are crucial for understanding such complex disorders and finding effective pharmacological treatments for them. Although there are universal models for NAS,

most models have major concerns like high costs, effectiveness, and the wellbeing of the model. The study proposes that black planaria (*Dugesia dorotocephala*) can be used as a viable animal model to replicate NAS in humans, because it has quantified withdrawal signs—planarian locomotor velocity (pLMV) and planarian seizure-like activity (pSLA) values,— has similar neurotransmitters to humans (e.g. serotonin, norepinephrine, etc.), similar central nervous system structure (CNS) and has the ability to regenerate to model CNS development. Three trials were conducted, all with two groups – a withdrawal group (experimental group) and a control group. An independent samples t-test was performed between each group for pLMV and pSLA values. In all three trials, there was a statistically significant difference between both groups for pLMV and pSLA values (pSLA, $p < 0.01$; trial one and two pLMV, $p < 0.05$; trial three pLMV, $p < 0.01$). The results align with NAS symptoms (seizures), showcasing mammalian-like withdrawal signs within withdrawal groups. The study suggests that *Dugesia dorotocephala* can be used as a novel animal model to replicate NAS.

Dieguez Kenshu -The Impact of the Type of Pre-Trained CNN Model on the Accuracy of Classifying COVID-19 from Lung X-Rays
Yorktown High School

At the onset of the COVID-19 pandemic, healthcare systems were subjected to significant stress. This experiment demonstrates that machine learning can relieve that stress by speeding up diagnosis. A Convolutional Neural Network (CNN) was created that can classify lung X-rays as 1) COVID-19, 2) viral pneumonia, or 3) no disease. CNNs are neural networks that use convolutional and pooling layers to find features in images; pre-trained learning was added to the neural network in the experiment to increase accuracy. The CNN in this experiment was built using the Tensorflow and Keras libraries with the language Python. Six pre-trained models were tested, and their accuracy was measured: 1) InceptionV3, 2) MobileNet, 3) ResNet50, 4) VGG16, 5) EfficientNetB0, and 6) DenseNet169. The experiment demonstrated MobileNet performed the best with an average accuracy of 84.5% despite having the lightest architecture. Other studies corroborate my results reporting >99% accuracy when applying MobileNet, which performs remarkably well because it utilizes depth-wise separable convolutional layers. These are special convolutional layers that apply filters to each color channel individually and add up the output, which results in fewer parameters. Regular convolutional layers apply a filter to every color channel simultaneously. Depth-wise separable convolutional layers have less overfitting and increased speed due to fewer parameters, while also achieving equal or higher accuracy. Additionally, the images in this experiment are similarly sized to those MobileNet was trained on, which leads to better compatibility. Though 84.5% may seem impressive, it is nowhere near the required accuracy to be put into real-world practice.

Future experiments would attempt to increase the accuracy by adding more depth to the CNN and/or by adding data augmentation.

Avery Gagen -The Antimicrobial Efficacy of Various Active Ingredients in Face Washes on *Propionibacterium acnes*
Central Virginia Governor's School

The purpose of this research study was to evaluate and compare the inhibitive effects of face washes, with varying active ingredients, on *Propionibacterium acnes*, a common acne causing bacteria, to determine the most effective active ingredient in face washes. This study had three experimental groups: a benzoyl peroxide face wash group, salicylic acid face wash group, and a combined benzoyl peroxide and salicylic acid face wash group- with a distilled water group acting as the control. Sterile paper discs were soaked in their designated face wash and placed upon a smear plate of bacteria. Petri dishes were incubated at 37°C for 72 hours before their zones of inhibition were measured. The average diameters of the zones of inhibition created by the face washes were 0 mm from the distilled water, 8.14 mm for the benzoyl peroxide face wash, 11.4 mm for the combination of the benzoyl peroxide and salicylic acid face wash, and 14.9 mm for the salicylic acid face wash. The salicylic acid face wash produced the largest zone; my research hypothesis, that the combination of face washes would produce the greatest effect, was not supported. A single factor ANOVA test was run to analyze the results of this experiment, which produced a p-value of 1.7×10^{-26} ($\alpha = .05$). In addition, a post-hoc Tukey test showed that there were statistically significant differences between all groups. This research aims to give insight on which acne products are the most effective.

Evan Huizar -The Effect of Acute Exercise on Human Hearing
Mills E. Godwin High School

This study aimed to determine the effects of acute exercise on human hearing. Exercise or physical activity has been known to benefit the human body in a variety of ways such as losing weight, and improving cardiovascular and mental health, so it is hypothesized that it would have a benefit on hearing ability. Human participants were put to different types of exercises which were: weightlifting, running, and resting. Once they finished exercising, they were immediately given a "Hertz Hearing Test" in which the range of frequencies that could be heard was recorded. The control in this experiment was resting (no exercise). It was hypothesized that running, as it would increase the ability to hear a higher range of frequencies due to increased blood flow to the ear. The results of the experiment showed that those that lifted weights could hear slightly better than those that ran or were resting. Statistical data analysis demonstrated significant differences between exercise or activity (running vs. resting, weightlifting vs. resting, weightlifting). The results did not support the research hypothesis. It is believed that the results are due to chance or an independent variable. These results could lead to a newfound interest in exploring what other aspects of body exercise could improve.

Sophia Jagels -The Effect of Alternative Natural Laxatives on Stomach Acid pH
Mills E. Godwin High School

This experiment was conducted to show which alternative natural laxative tested should be researched further for the benefit of patients with gastroesophageal reflux disease (GERD) and constipation. Recently, studies have shown a connection between constipation and GERD, but the use of common treatments for these conditions can cause unwanted side effects. Natural treatments like some juices, which also act as natural laxatives to ease constipation, could aid in managing GERD by acting similarly to an antacid, neutralizing stomach pH, but in a safer manner. In this experiment, 25 mL of 0.1 M HCl, simulated stomach acid, was poured into 20 mL of either Aloe vera juice, prune juice, pear juice, or no juice, the control. The pH of the resulting solution was measured and recorded via a pH meter. It was predicted that if Aloe vera juice was mixed with HCl, then it would cause the greatest increase in pH. Results showed that prune juice had the greatest mean stomach acid pH (2.60) compared to Aloe vera (2.14) and pear juice (1.97), therefore not supporting the research hypothesis. The conducted t-tests showed that all data sets were significant. This may have occurred because prune juice had the highest fiber content, which has been shown to reduce gastric acidity. Further research could include studying the effects of natural treatments, like the ones tested, on patients that struggle with GERD and constipation so that these patients' quality of life can improve.

Janes, Violet-The Effect of Patient Age on Bracket Failures
Mills E. Godwin High School

The purpose of this project was to discover how age affects the time before a patient loses a bracket, accounting for the factor of age-related compliance. Enamel content decreases and weakens with age, making it more difficult for a bracket to remain bonded to a tooth. Because of this, it was hypothesized that if a patient is older, then they will lose a bracket sooner. The dependent variable is the number of days before the first broken bracket. The independent variable levels include ages 0-20, 21-40, 41-60, and 61-80. Because treatment is provided to patients of all ages, there is no control. The patient data was collected, recording only their age, start of treatment, and date of first broken bracket, keeping the patient anonymous. Only data of patients with good oral hygiene and compliance were used. The average number of days before the first broken bracket was 494, 432, 281, and 155, respectively. The results strongly supported the research hypothesis as the oldest age group lost brackets sooner than the youngest group. The t-test deemed all result comparisons significant aside from 0-20 years vs 21-40 years. This is likely due to significant enamel erosion beginning to occur at 40. Because older patients lose brackets sooner, it implies that the age-related changes in enamel are significant enough to affect bracket bonding. Therefore, age-related changes in enamel should be considered when formulating a patient's treatment plan. This could prevent a patient's treatment time from prolonging due to broken brackets.

Jose Jerin -The Effect of Added Carotenoids on Bacterial Resistance in *C. elegans*
Mills E. Godwin High School

This experiment was conducted to determine how different carotenoids affected the mortality of *C. elegans* when exposed to a bacterial infection. The data from this experiment could benefit underprivileged areas where access to antibiotics is limited. It was hypothesized that if beta carotene was given to *C. elegans*, then their mortality rate would be the lowest. Four petri dishes were prepared with 30mL of nematode growth agar each. In one dish, 0.5 grams of one percent beta carotene was added. In another dish, 0.1 grams of one percent lycopene was added. In another dish, 0.1 grams of one percent lutein was added. The remaining dish was left unaltered for the control. Each dish was then mixed to dissolve the carotenoids. The dishes were left to harden for 20 minutes then streaked with an *E. coli* OP50 culture. Twenty-five *C. elegans* were added to each of the plates. After one day, 1 mL of *E. coli* (K-12 Strain) in nutrient broth was added to each of the plates. After one day, the results were measured. The mortality rate for control, beta carotene, lycopene, and lutein groups were 64%, 36%, 40%, and 44%, respectively. The analysis of the data supported the hypothesis. The results of the t-tests showed that all the data was significant, and the mean shows beta carotene has the greatest effect on *C. elegans* mortality rate under bacterial infection. Beta carotene performed the best because it acts as a provitamin for vitamin A, an anti-inflammatory, and an antioxidant.

Myah Kelso -The Effect of Phenacetin Exposure on Fruit Fly Reproduction
Central Virginia Governor's School

The purpose of this research was to determine if Phenacetin affects the *Drosophila melanogaster* reproduction system. As a model organism, the outcome has implications to human health. Phenacetin has been banned in several different countries but is still found in everyday products that humans use. For example, facial hair bleach, hair color, household items, and women's depilatories still contain Phenacetin. The fruit flies were placed in vials for a period of about two and a half months. 0.67 grams of Phenacetin was distributed between seventy-five vials. The virgin female fruit flies had 24 hours to mate before they were placed in the petri dish for egg count. This research concluded as statistically significant coming from the numerical values from the Chi-Square test. The Chi-Square had a value of 11.879 and the critical was 3.84. The alpha value that was used was .05 with a p-value of .0057. The research hypothesis, that the flies that were exposed to the Phenacetin would lay less eggs than the control flies, was supported by this data. The flies that were exposed to Phenacetin laid 104 eggs in total with 8 trials, while the control flies laid 160 eggs with the same number of trials. The outcome of the data shows that Phenacetin has some sort of effect on fruit flies' reproduction system which associates with human health as they have been used as a testing model for humans for over 100 years.

Deephanshi Kumar -The Effect of Different Concentrations of Polypropylene and Polyethylene Microplastics on the Heart Rate of *Daphnia magna*.
Maggie Walker Governor's School for Government and International Studies

Microplastics have become an increasingly dangerous threat to the environment in the past 70 years. As microplastics enter global marine ecosystems, they eventually find their way into food products and seafood, posing a severe risk to human health. The purpose of the research was to understand how the ingestion of different microplastics affects the heart organ of daphnia magna. The hypothesis was "If Daphnia Magna is exposed to 2% polyethylene solution, then it will have the greatest change in heart rate." There was a control of 0% of microplastics. The other levels included 1% polypropylene, 2% polypropylene, 1% polyethylene, and 2% polyethylene. There were 5 trials in each level, so the daphnia were transferred into separate containers and exposed to the solutions for 5 minutes, after which they were observed under a compound light microscope. The heartbeat (beats per minute) was observed and recorded. It was found that the mean heartbeat was 124.8 for the control, 145.2 for 1% polypropylene, 158.4 for 2% polypropylene, 129.6 for 1% polyethylene, and 157.2 for 2% polyethylene. The p-value was 0.0002 and it was concluded that the 2% solutions of both plastics had the highest heart rates. The null hypothesis was rejected, and the data supported the conclusion that both polypropylene and polyethylene microplastics cause an increase in heart rate. This is likely because the ingestion of microplastics causes inflammation. Furthermore, microplastic ingestion can cause oxidative stress which leads to excessive cell growth and improper organ function. The study conducted provided evidence that microplastics, even in small quantities, are detrimental to the health and function of organisms. This is especially significant for the medical field as plastic production continues to increase. This research will be implementable in food distribution and produce industries to ensure safer consumption.

Medicine & Health B (HS MDH-B)

First Place

Layla Moussavi, Raianne Ferrer & Lyla Browne - Modeling the Effect of Hyperglycemia on Fertility of *Caenorhabditis elegans*

Governor's. School @ Innovation Park

Diabetes, a prevalent condition characterized by hyperglycemia, can affect human fertility. The animal model *Caenorhabditis elegans* is used to research human diseases due to its molecular-level similarities and ethicality. This study's purpose was to determine at which glucose concentration an effect on *C. elegans* fertility was initially observed. *C. elegans* were transferred onto 15 experimental plates which were seeded with *E. coli* OP50 containing glucose concentrations in increasing increments of 4 mM from 16 mM to 32 mM, based off glucose levels in human diabetics, and each with 3 trails. After 7 days of growth, the worms were placed into a bleach solution to count their eggs. Data collected partially supported the hypothesis, since a decrease in the number of eggs/worms was observed with a correlation value of -0.9255, meaning there is a significant relation between the egg count and increased concentrations of glucose. A linear decrease was observed in the egg counts (p -value < 0.01): the control (16 mM), that simulated the average blood glucose levels for adults, had an average of 10.89 eggs/worm, 20 mM had 10.22, 24 mM had 9.44, 28 mM had 7.06, and 32 mM had 4.22. Since *C. elegans* is an animal model for humans, these results can be applied to diabetics, who display high, uncontrolled levels of blood sugar.

Second Place

Sarayu Mandalapu - The Effect of Various Water-resistant Sunscreen Formulas on UV Protection Underwater, Evidenced by the Amount of Color Change in UV Beads After 10 Minutes

Clover Hill High School

Water-resistant Sunscreens are common products used to provide UV (ultraviolet) protection underwater. The main objective of this experiment was to determine which kind of water-resistant sunscreens provided the most UV protection underwater. The hypothesis was that Kiehl's Ultra-Light UV Defense Sunscreen would provide the most UV protection underwater. Four UV beads were covered with the respective sunscreens with one uncovered UV bead for the control. The 5 beads were placed in buckets, filled with water, in the sun for 10 minutes. After 10 minutes, the sunscreen was wiped off the beads and the color, using the LAB color space, was measured using the Aurora app. Overall, Ocean Potion provided the most UV protection with its mean lightness value of 72.5 and channel A values of 28.0. La Roche-

Posay Anthelios Sunscreen and EltaMD UV Sport Sunscreen provided similar lightness and channel A values with La Roche-Posay Anthelios sunscreen having 72.1 and 29.0 respectively and EltaMD UV Sport sunscreen having 69.9 and 28.9 respectively. Kiehl's Ultra-Light UV Defense had the least UV protection with its lightness of 64.2 and its channel A of 34.0. The null hypothesis was rejected using an ANOVA test; however, the research hypothesis was not supported. Sunscreens with thicker consistencies like Ocean Potion Sport Sunscreen may provide more UV protection as they are less likely to slip off the skin and smooth surfaces, like UV beads.

Third Place

Coston Pritchett -The Effect of Zanfel vs. Homemade Herbal Poultice on Percentage of Remaining Urushiol
Clover Hill High School

This experiment was designed to answer the question of whether or not jewelweed was an effective alternative to Zanfel, a somewhat expensive solution to removing urushiol from skin. The hypothesis was that if two pieces of faux skin were coated in equal amounts of urushiol and "treated" with jewelweed poultice and Zanfel respectively, the poultice would remove an equal or greater amount of urushiol compared to Zanfel. The experiment was done by coating a piece of faux skin with a small amount of poison ivy, then removing the poison ivy sap using either Zanfel, jewelweed, or nothing for the control. The skin was then wiped with a color changing urushiol sensitive wipe, of which an image was taken and analyzed with ImageJ. Principally, the results were that Zanfel vastly outperformed jewelweed in removing urushiol. The null hypothesis was not rejected, and the data gathered did not support the research hypothesis.

Honorable Mention

Sara Robinson - Comparing the Effectiveness of Tylenol Products on Dissolving Time
Central Virginia Governor's School

The purpose of this study was to determine whether the type of Tylenol product had an effect on its dissolving time. Five groups of Tylenol products were submerged in simulated gastric acid and timed to see how long they took to dissolve. To simulate gastric acid, 7.375g of Sodium Chloride (NaCl), 3.125g of Sodium Bicarbonate (NaHCO₃), and 1.725mL Potassium Chloride (KCl) were added to water and adjusted to a pH of 1.2 using Hydrochloric Acid (HCl). The mean dissolving times were 2.444 minutes for Regular Strength Tablets (325mg), 5.002 minutes for Extra Strength Rapid Release Gel (500mg), 5.125 minutes for Extra Strength Caplets (500mg), 14.893 minutes for Extra Strength Coated Tablets (500mg), and 1440 minutes for Regular Strength Liquid Gels (325mg). After data collection a one-way ANOVA was used, which gave a p-value of 1×10^{-232} (compared to an alpha level of .05) and determined that there was statistical significance. A post-hoc Tukey test was used to locate the significance between the five groups using a Dmin of 1.815. Significance between groups was evident in all but two groups: Extra Strength Rapid Release Gel

(500mg) and Extra Strength Caplets (500mg). The research hypothesis, that the Tylenol Extra Strength Rapid Release Gel (500mg) would dissolve the quickest, was not supported. In conclusion, the type of Tylenol product did have a significant effect on the dissolving time. By exploring the effects of drugs on our body when metabolizing, we can lessen the negative effects and maximize the positive ones, thus leaving humans healthier.

Honorable Mention

Sean Kim - The Effect of Diphenhydramine Hydrochloride on the Regeneration of *Dugesia dorocephala*
Central Virginia Governor's School

The purpose of this study was to determine how Diphenhydramine hydrochloride (DPH) affected the regeneration rate of *Dugesia dorocephala*. Concentrations tested were 0 mg/500mL, .0008 mg/500mL, .0013 mg/500mL, and .0015 mg/500mL. Planaria were measured and observed using the Leica EZ 40 microscope. This study concluded that Diphenhydramine hydrochloride does have an effect on the regeneration rate of *Dugesia dorocephala*. Performing a one-way ANOVA test yielded a p-value of .0065 with the alpha value set to .05 this indicated significance in the data. A post-hoc Tukey test indicated that there was a significant difference in the length of planaria regenerated in the 0mg/500mL test group only. The research hypothesis stating that if exposed to different concentrations of Diphenhydramine hydrochloride, the population of *Dugesia dorocephala* with the highest concentration of DPH in their water habitats would experience the slowest rate of regeneration was partially correct as the test group with the lowest concentration of Diphenhydramine hydrochloride (0mg/500mL), experienced the most regeneration. In conclusion, this study found that Diphenhydramine hydrochloride does have an adverse effect on wound healing and cellular regeneration and has implications for human health related to the use of DPH and healing rates.

Honorable Mention

Megan Nelson -The Effect Penicillin has on *Staphylococcus epidermidis* Versus Homeopathic Ingredients
Central Virginia Governor's School

The purpose of this study is to discover whether penicillin would work better than the homeopathic ingredients; honey, lemon juice, and garlic oil, against *Staphylococcus epidermidis*. The bacteria were grown in seven test tubes and cultivated to obtain substantial growth in the medium. Then, aseptic technique was used to transfer the bacteria on petri dishes containing nutrient agar. Blank, sterile paper disks were dipped into the honey, lemon juice, and garlic oil, along with water as the control group, before they were placed on petri dishes coated with *Staphylococcus epidermidis*. The means from the trials were 0cm for the dH₂O, 1.74cm for the honey, 1.87cm for the penicillin, 1.94cm for the lemon juice, and an outstanding 4.41cm for the garlic oil. A single-factor ANOVA indicated significance because the p-value of 1.13×10^{-8} was much smaller than the alpha value of .05. Afterward a post-hoc Tukey test affirmed that there

was significance within the groups; garlic oil was significantly different from every group except for the lemon juice. The research hypothesis which stated honey would be most effective in inhibiting the growth of *S. epidermidis* was not supported. While homeopathic ingredients and the antibiotic grew zones of inhibition, the homeopathic ingredients were suggested to be just as, if not more effective than antibiotics.

Kaitlin Madison -The Enzymatic Activity of Lactase
Washington-Liberty High School

Lactose hydrolysis is the process in which lactose, an indigestible substance, is catalyzed by lactase. Once catalyzed, it is then broken down into two monosaccharides glucose and galactose, which can easily be digested. However, some humans are not able to produce lactase enzymes, thereby making it difficult to digest lactose. The purpose of this experiment is to provide information to those who are lactose intolerant in regard to which type of milk is best hydrolyzed by taking supplementary lactase. In this experiment 1% milk, 2% milk, whole milk, and skim milk are being tested to show the amount of glucose it produces as a result of lactose hydrolysis. It was hypothesized that if milk samples with different fat level contents are tested to see how much glucose has formed due to lactose hydrolysis after two minutes, then the test of whole milk and enzyme solution will have the greatest concentration of glucose because the whole milk has the greatest amount of lactose and when combined with the enzyme solution it will produce the greatest amount of glucose. The null hypothesis was that if different milk samples are tested to see how much glucose has formed because of lactose hydrolysis after two minutes, there will be no difference in the amount of glucose formed. However, the null hypothesis was rejected. The experiment was conducted by allowing 10 ml of each milk sample to hydrolysis with lactase for two minutes. After hydrolysis, results were recorded. The results displayed that whole milk produced the most glucose with 610 mg. While one percent milk produced the least amount of glucose, 120 mg, as a result of lactose hydrolysis. Two percent milk had the second largest amount of glucose created, 290 mg, while fat free was behind with 220 mg produced. The data differed, therefore making this experiment effective in proving which type of milk produced the most lactose as a result of lactose hydrolysis.

Benjamin Merkel -The Effect of Spray Sunscreen vs. Lotion Sunscreen on the Change in RGB of UV Beads
Clover Hill High School

The purpose of this experiment was to determine whether spray sunscreen or lotion sunscreen would be more effective at blocking out the sun's ultraviolet rays. Ultraviolet radiation is often harmful to humans with excessive exposure to it being the leading cause of skin cancers. However, sunscreen is efficacious in inhibiting ultraviolet light's ability to reach the skin, so it is vital to ascertain which method of sunscreen delivery is most effective. The hypothesis was that using lotion sunscreen rather than spray sunscreen would result in a less drastic change in the RGB of UV Beads, and, by

extension, would be more effective at protecting from the sun's UV rays. Thirty trial rounds were conducted, with each trial round consisting of one bowl containing a UV color changing bead for each of the three independent variable levels, those being no sunscreen (control), lotion sunscreen, and spray sunscreen. Plastic wrap was placed over each bead and the sunscreen was applied to it, corresponding with its independent variable label. The three bowls were all tested at once, being exposed to a UV lamp for fifteen seconds. Then, pictures were taken of the beads and compared to pictures taken before the experiment before being analyzed to find the change in the R, G, and B levels of the beads. This process was then repeated until thirty trial rounds had been conducted. The R values experienced a mean change of 28.0 for no sunscreen, 21.4 for lotion sunscreen, and 23.4 for spray sunscreen. The G values experienced a mean change of 40.1 for no sunscreen, 31.1 for lotion sunscreen, and 28.7 for spray sunscreen. The B values experienced a mean change of 29.1 for no sunscreen, 33.3 for lotion sunscreen, and 30.1 for spray sunscreen. The data was tested using a One-Way ANOVA test and found that the majority of the dependent variables were statistically significant. With this, the null hypothesis was rejected for two of the dependent variables but was not rejected for the third. Additionally, the research hypothesis was not supported because there was no distinguishable difference between the efficacy of spray and lotion sunscreens.

Anna Mohanty -The Effect of Axon Diameter on Heart Rate Variability
Washington-Liberty High School

Patients with autism spectrum disorders (ASD) have a 45.9% higher likelihood of developing early onset cardiovascular disease (CVD), a rate independent of congenital predisposition and obesity. This experiment aimed to investigate the cause of this discrepancy by measuring the effects that genetic differences in the functional neurological patterns of autistic patients on cardiac neuromuscular signaling. Specifically, the genetic traits that result in ASD patients having similar neuronal conversion trends to those seen in epilepsy, a condition which has been causally linked to a 25% greater arrhythmia risk. This trait was the decrease in neuronal axon diameter for ASD patients. To model this, a novel circuit model of the cardiac vagus nerve was constructed using an adapted Zener diode with an integrated electrocardiogram. The data inputted into the circuit varied based on voltage levels calculated from the pre-measured percent reduction ranges for axon diameter, and the simulated EKG readings were assessed for cardiac signaling capability based on heart rate variability (HRV). A statistically significant decrease in HRV was found in the groups representing autism-functioning levels, indicating that the hypothesis that people with ASD were inherently at risk for heart disease was supported. More so, the circuit is an effective adaptation of an EKG for evaluating CVD risk, since instead of measuring hormone-regulated heart output, it can perceive the results of early CVD effects on neuronal stimulation. Thus, it can be applied for the early detection of heart disease symptoms and accurate risk determination for a range of cardiac conditions.

Aarushi Nayak -The Effect of Glucose as a Dietary Additive on the Lifespan of *C. elegans*
Mills E. Godwin High School

The purpose of this study was to determine if glucose had a direct effect on lifespan, and if so, what level was ideal. Many people across the world suffer from Type 2 diabetes which can be a result of hyperglycemia, which is raised glucose concentration in the blood. The results from this experiment could be used in diabetes research to develop a more effective way of preventing and combatting these issues. Glucose is thought to have a negative effect on the body. However, it is necessary for life. Therefore, it was hypothesized that if 20 mmol/L was given to *Caenorhabditis elegans* as a dietary additive, then the lifespan would be the longest. The smallest glucose concentration was 0 mmol/L while the largest was 80 mmol/L. The 0 mmol/L level served as the control. To perform the experiment, each glucose solution was made and was swabbed on one quarter of the original culture of *C. elegans*. To reculture them on new Petri dishes, the other plates were swabbed with *Escherichia coli*, to act as a food source, then a small section of the original culture was cut out and placed in the middle of the new plate. They were then swabbed with the corresponding glucose solutions, and after a couple days, were observed over time to measure the lifespan. The mean results for each level were 21 days for the control, 20 days for the 20 mmol/L level, 18 days for the 40 mmol/L level, and 14 days for the 80 mmol/L level. Through the use of t-tests, all data was proven to be statistically significant, meaning that the results were due to the manipulation of the independent variable. Various studies show similar results, as glucose is often associated with shorter lifespans due to the IIS, insulin signaling pathway in *C. elegans*. This is also directly correlated with the aging process, so when the glucose levels were too concentrated, it shut down, resulting in a shorter lifespan.

Ariya Patel - A Novel Lateral Flow Immunoassay for the Detection of Parvovirus B19 Antigens in Urine
Southwest Virginia Governor's School

Parvovirus B19 (*Primate erythroparvovirus 1*) is a common respiratory virus known for causing fifth disease and chronic anemia among young children, pregnant females, immuno-compromised individuals, and elderly. The two current clinical tests for Parvovirus B19, blood testing and polymerase chain reaction (PCR) testing, are cost-prohibitive for low-income individuals, and pose an undue risk for the immuno-compromised and elderly. In order to provide an affordable and reliable alternative to address these shortcomings, a lateral flow immunoassay test was designed and developed for the detection of Parvovirus B19 antigens in urine. Thirty-six lateral flow immunoassay tests were constructed and tested to quantify the sensitivity and specificity of the project design. The results of the experimentation indicate a 90% level of sensitivity and a 100% level of specificity for the lateral flow immunoassay. These test results were compared to the sensitivity and specificity levels of the Parvovirus B19 polymerase chain reaction test results to validate the effectiveness of the lateral flow immunoassay

Anooshka Pendyal - Utilizing Machine Learning and Tissue Specificity as Markers in Acute Myeloid Leukemia
Deep Run High School

Acute myeloid leukemia (AML) is a deadly form of leukemia that needs to be treated early and aggressively. Thus, effective predictive markers should be developed so that the disease can be diagnosed, and treatment can be given as early as possible. Tissue-specific transcripts are transcripts with elevated expression in one tissue type, and recent studies have revealed that these transcripts could be effective markers in studying cancer. There has also been growing interest in investigating how machine learning models, such as a DNA language model known as DNABert, can be applied to understand new areas of research in biology, such as the role of tissue-specific transcripts in cancer. The aim of this research was to build a robust classifier that distinguishes AML samples from normal samples based on expression of tissue-specific transcripts and to further fine-tune DNABert to improve its performance in discriminating tissue-specific promoters from nonspecific promoters. The data used in this project was obtained primarily from genomic databases such as GTEx and TCGA. DNABert fine-tuning did not perform well (65.62% accuracy) but the robust classifier performed extremely well (100% accuracy), showing that expression of tissue specific transcripts can differentiate AML samples from normal samples. This research project was able to conclude that tissue-specific transcripts can be used as effective predictive markers as they are able to discriminate cancerous samples from noncancerous samples. As work on this project continues, the data preparation steps in fine-tuning DNABert should be revised, and AML should be further subtyped to identify significant differences in survival between subtypes.

Isha Prem - The Effects of Zinc, Aluminum, & Iron on the Behavior of PTL-1 *Caenorhabditis elegans* and Alzheimer's Disease
Governor's School @ Innovation Park

Alzheimer's disease (AD) is a progressive, degenerative disorder that affects the brain and results in the loss of cognitive and memory functions. In AD, abnormal protein deposits build up in the brain, leading to the death of brain cells. Studies show that metals can progress the buildup of protein deposits, which supplements AD. Zinc sulfate, Aluminum nitrate, and Ferrous sulfate are common metals that humans encounter daily. These metals are present in medications, foods, water, and environmental factors such as the air an individual breathes. To evaluate the extent to which these metals affect *Caenorhabditis elegans*, the test species that show similarities to humans, a 0.00189151 g/mL concentration of iron, aluminum, and zinc is administered to the *C. elegans* through seeding. Thrash counts were analyzed afterwards to evaluate the motility and lifespan of *C. elegans* compared to the thrash counts of control *C. elegans* based on the behavioral reactions of the *C. elegans*. The results show that the zinc exposed worms averaged 49 thrash counts per minute, the iron exposed worms averaged 46 thrash counts per minute, and the aluminum exposed worms averaged 48 thrash counts per minute. Overall, exposure to metals, particularly iron, detrimentally impacts PTL-1 worms which leads to TAU protein buildup. Therefore, it can be inferred that metal exposure exerts a negative influence on AD.

Sydney Rader - A Study on the Potential of Vitamin D Deficiency in Adolescents
Chesapeake Bay Governor's School

Vitamin D deficiency is a medical issue for patients of all ages. This critical vitamin helps the body absorb calcium and phosphorus needed for strong bone development. Worldwide, approximately 1 billion people are affected by vitamin D deficiency, and 50 % of the world's population are insufficient in vitamin D (*Siddiquee et al., 2021*) The purpose of this study is to determine whether adolescents are obtaining the daily recommended value of 600 IU of vitamin D to prevent hypovitaminosis D. A survey was sent out to students with a variety of different lifestyle habits (athletes, non-athletes, advanced studies students, regular students, etc.) to analyze whether they acquired the recommended average amount of vitamin D in international units (IU) daily. Studying the presence of this vitamin in adolescents is important, as without the needed amount, it can lead to pernicious illnesses later in life. Throughout the experiment, the majority of participants did not receive the recommended amount of vitamin D. Out of the 17 participants, only 4 of them received the RDA from food alone. By getting more sunlight, drinking more milk, eating vitamin D fortified foods, or even taking a supplement, the chances of acquiring vitamin D deficiency and developing relating health issues can be reduced.

Jenna Saleh -The Effect of Foods that Mimic ACE inhibitors on Flame Cell Function of *Dugesia dorocephala*
Central Virginia Governor's School

The purpose of this study was to determine if foods that mimic angiotensin-converting enzyme (ACE) inhibitors have an effect on flame cell function of *Dugesia dorocephala*, and in turn, human kidney function. Five groups of *Dugesia dorocephala* were randomly assigned a different food: tuna, seaweed, sardine, fish flakes, or the control, which was fed nothing over the course of the study. Flame cell function was measured by how much nitrogenous waste (in the form of ammonia) was released into the water using the Vernier Go Direct Ammonia Probe. Analysis of the data included single-factor ANOVAs: one analyzing daily ammonia measurements, and another analyzing the change in ammonia each week. The first ANOVA determined significance with a p-value of 9.6×10^{-28} when compared to the alpha value of .05. A Tukey test with a Dmin of 3.77414 concluded that seaweed did not have a significant effect on flame cell function. The second ANOVA determined significance with a p-value of .039 when compared to the alpha value of .05. A Tukey test for this output with a Dmin of 4.89841 determined that the sardine group had a significant change in ammonia. The research hypothesis which stated, if *Dugesia dorocephala* were fed foods that mimic ACE inhibitors their flame cell function will increase was partially supported due to statistical significance being found within some groups. In conclusion, foods that mimic ACE inhibitors were shown to have an effect on flame cell function of *Dugesia dorocephala*.

Saniya Sangle -The Effect of Dietary Supplements on the pH of Stomach Acid
Mills E Godwin High School

Use of dietary supplements is widespread across the world for multiple reasons. Due to COVID-19 pandemic sale of dietary supplements increased by 20%-110% with increasing consumer focus on immunity and overall wellness. In United States 77% of Americans take vitamins or dietary supplements but only 24% have nutritional deficiencies. The effect of commonly consumed dietary supplements Zinc, Turmeric, Ginger, and Echinacea on pH of stomach acid, simulated using white vinegar which has a similar pH range 1.5-3.5. Maintaining pH level of stomach acid is very critical for digestion and prevention from viral, bacterial infections. Different dietary supplements impact the pH levels of stomach acid differently. It was hypothesized that if a Turmeric tablet was dissolved into 30mL of white distilled vinegar, then the pH of the mixture would be between 1.5 to 3.5 which is same as pH of stomach acid, implying that when Turmeric consumed in recommended daily value it may help increase or maintain acidity of stomach acid. Other dietary supplement mixtures formulated with 30mL of white vinegar showed higher pH levels than Turmeric. A daily suggested quantity of supplement dissolved in 30mL of while vinegar, and the pH of the mixture was measured using pH strip. Twenty-five trials were performed for each supplement type. The results of the experiment have been discussed in terms of mean, variance, standard deviation, and t-test. Post experiment observations and data supported hypothesis. This study revealed that the daily recommended value of Turmeric will decrease the pH of stomach acid more than Zinc, Ginger, and Echinacea supplements.

Nishorgo Sarkar - Effects of Diosgenin, a Regulator of Inflammation, on Inflammatory Markers in Hepatocellular Carcinoma Cells
Mills E Godwin High School

Diosgenin is a steroid found in various plant species, notably *Trigonella foenum-graecum*, commonly known as fenugreek. It has shown various pro-apoptotic, anti-inflammatory, and anti-proliferative effects, which, like many other phytochemicals, are crucial in research on hepatocellular carcinoma treatment due to their wide function and generally low side effects. An MTT assay and real-time PCR test were performed to measure the proliferation and expression of inflammatory cytokines of HepG2 and HuH-7 HCC cells. HCC cells were treated with four concentrations of diosgenin in ethanol, these being 0 μM (control), 12.5 μM , 25 μM , and 50 μM , treated with MTT, and had absorbance measured using a Promega Glomax. For the qRT-PCR test, HCC cells were treated with 0 μM (control) or 12.5 μM of diosgenin and 0 μL (control) or 10 μL of lipopolysaccharide to stimulate inflammation, with inflammatory cytokine levels measured from collected and purified RNA. It was hypothesized that diosgenin would decrease cell proliferation and cytokine expression in a dose-dependent manner. Cell proliferation had statistically significant decreases with increasing dose, with each t-test against the control significant at a 0.001 level. Inflammatory cytokine expression was variable but had insignificant differences to the control at a 0.05 level. These results indicate that diosgenin decreases

cell proliferation, but not inflammatory cytokine expression in HepG2 and HuH-7 cells. In future studies, research into non-cancer and cancer cells in addition to cell and tumor morphology would be key in understanding potential adverse effects.

Medicine & Health C (HS MDH-C)

First Place

Caroline South -The Effect of Over-The-Counter Medicine Coating on the Release Time in a Low pH Environment
Washington-Liberty High School

Often over-the-counter medicine is coated to allow the individual to swallow the medicine easier. The coating needs to dissolve or release the medicine before the medicine can go into the bloodstream. Once in the bloodstream the medicine can help relieve the patient's pain. The purpose of this experiment was to test what type of Advil (Ibuprofen) coating releases the medicine at the fastest rate. The different coatings tested were tablets, caplets, liquid-gels, and liquid-gel minis; there was no control. It was hypothesized that if different kinds of over-the-counter medicine coatings are put in a low pH environment, then the caplets will release at a faster rate, because the caplet has a film coating, which has been proven to release the medicine faster than the other coatings. The independent variable was the type of over-the-counter medicine coating, and the dependent variable was the percent decrease from the original weight of the over-the-counter medicine coating. The pH of a 1M solution of hydrochloric acid was tested, and the pH measured to an acidity level of 1.5, which was in range of the average pH of gastric acid in the human stomach. A solution was heated to 37 degrees Celsius, the approximate temperature of the stomach. The weight of each Advil pill was measured before it was dropped into 20ml of the solution of hydrochloric acid. The pills remained in the solution for seven minutes before being removed and again weighed on a scale. The null hypothesis was if different kinds of over-the-counter medicine coatings are put in a low pH environment, then there will be no difference in the weight of the over-the-counter medicine coatings between the tested groups. An ANOVA test was conducted to determine the significance of this project's data. The calculated p-value was 6.0787E-09, which is less than the critical value of 0.05, which means that the null hypothesis can be rejected.

Second Place

Lilly Wood - A Mutigenerational Study Regarding the Effects of Titanium Dioxide on the Reproductive Rates of *Drosophila melanogaster*
Central Virginia Governor's School

The purpose of this study was to determine the adverse effects of Titanium dioxide on *Drosophila melanogaster*, an invertebrate typically used as a model organism for humans, over multiple generations. The study was conducted in a

local high school laboratory during November of 2022. Three original colonies of w1118 White Mutant *D. melanogaster* were used to gather 24 virgin females, 8 females in each test group. Every virgin female was placed in an individual vial. Each vial contained a standard food medium mixed with different concentrations of Titanium dioxide. The control group contained no Titanium dioxide, the low concentration group contained 0.1mg per 10 mL vial, and the high concentration group contained 0.3 mg per 10mL vial. The egg laying for each female was counted and then the emerged virgin females from these groups were used to start a new generation. A two-way ANOVA test returned three p-values: .06 for the samples (generations), 2×10^{-16} for the columns (concentrations), and .56 for the interaction effect, with a set alpha value of .05. This showed that the data were somewhat statistically significant, with an effect between concentrations of Titanium dioxide, but no effect between generations. This means that the hypothesis, which stated that Titanium dioxide, when added to the food medium of *Drosophila melanogaster*, would decrease the reproduction rate and will continue to decrease the reproduction rate in consequent generations, was partially supported. The findings of this study can be used to guide future research on the adverse effects of Titanium dioxide on the female reproductive system.

Third Place

Yana Shah - Data Analysis of Interpretation Errors Made When Reading CT Angiograms of the Head and Neck
Mills E Godwin High School

A medical error is an adverse outcome of medical treatment that occurs more often than it should, regardless of whether it affects the patient's care. When reading CT angiograms (CTAs) of the head and neck, radiologists receive detailed coverage of the aortic arch to the frontal sinus, as well as information about targeted blood vessels. While these large scans can greatly benefit a patient's health, they can also result in the missed detection of incidental findings and anomalies. This study aims to determine the frequency of missed incidental findings during the examination of CTAs of the head and neck and to identify the main reasons why radiologists fail to report them. Five volunteer radiologists were each randomly assigned 50 previously read cases and used the RADPEER system to score the original report with a score of 1, 2a, 2b, 3a, or 3b. In addition, if the case received a RADPEER score other than 1, an error classification (EC) score was assigned (from type 1 to type 8). This was an observational study, so there was no control group. It was hypothesized that there are many errors made by radiologists when reading CTAs of the head and neck and that in cases with missed findings, the main reason is that the discrepancy was overlooked. The results of the study showed that 29.6% of the cases had an error, and of those cases, 86.5% had an EC score of 1, which supports both research hypotheses. In addition, two chi-square tests were performed, and both the RADPEER score and EC score tests were shown to be statistically significant. Possible explanations for the significant number of errors found in this study include the concept of satisfaction of search and the limited number of subspecialty radiologists available to read complex cases in private practices, such as the one studied.

Honorable Mention

Annie Yuan -The Effect of Ascorbic Acid on DNA Methylation in HCT-116 Cells

Mills E Godwin High School

Methylation is an epigenetic modification that effectively silences the transcription of certain genes. In certain cases, hypermethylation may lead to the silencing of tumor suppressor genes, thus leading to uncontrolled cell proliferation. The purpose of this experiment was to test the effects of ascorbic acid on methylation levels. Three petri dishes containing human colon cancer cells were cultured. One dish was treated with a concentration of 250 μM of ascorbic acid, diluted in sterile water, while another was treated with a 500 μM concentration. A control group was chosen to remain untreated. It was hypothesized that greater amounts of ascorbic acid treatment would lead to less methylation. Following 24 hours, the DNA from the cells was purified and digested by restriction enzymes. The amount of methylation was quantified by running an agarose gel and measuring the pixel density of the undigested DNA, as one of the enzymes was blocked by methylation. The results showed that the 500 μM concentration treatment had the least amount of methylation, indicating that ascorbic acid treatment does promote demethylation of DNA. A regression was performed, and the F statistic was calculated to find the correlation between ascorbic acid treatment and methylation. The regression equation was significant at a level of 0.001. A possible explanation for why ascorbic acid decreases methylation is because it is a cofactor for enzymes which demethylate DNA. Further research should be done on how ascorbic acid impacts the p16 gene, a commonly mutated gene in cancer.

Honorable Mention

Nisarg Shah -The Effect of Different Neurotransmitter and Drug Concentrations on the Reuptake of APP+ in Different Neurotransporters

Mills E Godwin High School

The purpose of this experiment was to research the difference in potency between two monoamine neurotransmitters and the antidepressant paroxetine in different neuro-transporters. Lately, depression has become a concerning problem across the globe. The disorder has various treatments, the most common being medication, making it essential to continue research into antidepressants. Three groups of HEK-293 cells transfected with the neurotransmitter hSERT, hDAT, or OCT3, were perfused with imaging solution (IS), then with serotonin, dopamine, or paroxetine, then the APP⁺ and neurotransmitter/paroxetine solution. The control group only received IS and APP⁺. To determine the potency, the concentration at which 50% of the APP⁺ was blocked by the neurotransmitter or paroxetine, also known as the IC₅₀, was calculated using a nonlinear regression. The results showed that the difference between the IC₅₀ of dopamine and paroxetine in hDAT was not significant. However, the difference between both the IC₅₀ of serotonin and paroxetine in hSERT, and serotonin and paroxetine in OCT3 were significant. Since paroxetine is a Selective Serotonin Reuptake Inhibitor (SSRI), it must be more potent than serotonin in the monoamine neurotransmitters to outcompete

it. Paroxetine also needs to be more potent than serotonin in transporters such as OCT3 since they provide a large amount of reuptake. However, the potency compared to dopamine is unimportant since it was not made to inhibit the monoamine dopamine transporter. For further research, the effect drugs like paroxetine and other SSRIs should be tested on the uptake of APP⁺ in OCT3 and PMAT, another high capacity neurotransporter.

Honorable Mention

Emily Yang -The Effect of Sphingolipid Biosynthesis Inhibitors on Cell Viability
Mills E Godwin High School

The purpose of the experiment was to determine the effects of sphingolipid synthesis inhibitors on cell viability of mouse motor neurons (NSC-34). Niemann-Pick disease type C (NPC) is a lysosomal disorder that affects lipid metabolism, causing neurodegeneration. Around 43 infants are born with NPC annually in the United States, implying that the disorder is prevalent and that accessible treatment options are crucial for those affected. The rationale of the experiment was to see how the inhibitors affect NPC cell viability, because inhibiting sphingolipid synthesis reduces lipid accumulation, making it a possible treatment for NPC. In this experiment, NSC-34 cells were cultured in media and placed 96-well plates once confluent. Variations of U18666A, Myriocin, and Fumonisin B1 were given to cells based on the experimental group. The controls for the experiment were wild-type and NPC cells not treated with an inhibitor. Cell viability was measured by the number of living cells. It was hypothesized that if Myriocin is used to decrease sphingolipid biosynthesis in NPC cells, then cell viability will increase the most. The results showed that NPC cells with Myriocin had the greatest viability and compared closely to the wild-type cells. The results supported the research hypothesis. T-tests conducted on the data revealed that the results of the experiment are significant. It is believed that the results are due to the fact that Myriocin reduces lipid synthesis, inflammation, and oxidative stress, allowing for increased cell viability. The research conducted could lead to further studies that investigate other sphingolipid synthesis inhibitors.

Tanish Singh - Application of a Deep Learning Model for Effective Diagnosis of Osteosarcoma
Mills E Godwin High School

The purpose of this experiment was to test the effects of different osteosarcoma tumor types on the accuracy of a trained neural network. Osteosarcoma is a subset of bone cancer seen greatly in pediatric cases and young adults. It is characterized by the rapid production of abnormal bone tissue, leading to developing acute injuries. If left untreated, its malignant nature can spread and be life-threatening. There are several pathological detection methods for osteosarcoma, including X-ray, MRI, CT, and microscopy. Pathologist misdiagnosis can occur because of the diversity in neoplastic formation. In recent years, researchers have explored using neural networks, a machine learning

algorithm, for detection. Neural networks can analyze medical images and identify patterns, leading to a more accurate diagnosis and enhanced patient outcomes. A dataset consisting of hematoxylin and eosin (H&E) stained cells of three osteosarcoma tumor types, Viable Tumor, Non-Viable (Necrotic) Tumor, and Non-Tumor was utilized for the training of a convolutional neural network (CNN). The neural network structure was of a VGG19 and consisted of 18 convolution layers, max-pooling layers, and connected layers for feature extraction. With the main metric being validation accuracy, the multiclass classification score was 96.3%. There are several areas of future studies in which osteosarcoma detection with a neural network could lead to. The development of advanced algorithms and models could allow for greater accuracy and efficiency to detect tumors from medical imaging. The patient outcome would be increased based on diagnosis speed and treatment times. Analyzing large amounts of data could lead to advances in reducing the future risk of disease in patients.

Janhvi Spahr -The Effect of Pandemics on Life Expectancy in Different Regions of the World Since 1950
Washington-Liberty High School

The purpose of this experiment is to see if other pandemics in the past 70 years have had an impact and the severity of the impact on life expectancy in different regions of the world. The hypothesis is if there is a pandemic during a certain year, then the annual life expectancy rates of each region will decrease in corresponding years, because there will be a higher, unnecessary mortality rate during those years. The null hypothesis is if there are pandemics during certain years, then there will be no impact on life expectancy. The pandemics chosen for this experiment are the Asian Flu (H2N2 Flu) pandemic, Hong Kong Flu (H2N2 Flu) pandemic, HIV/AIDS epidemic, Swine Flu (H1N1 Flu) pandemic, and the COVID-19 pandemic. The regions of the world that will be tested are Sub-Saharan Africa; Northern Africa and Western Asia; Central and Southern Asia; Eastern and South-Eastern Asia; Latin America and the Caribbean; Ocean (excluding Australia and New Zealand); Australia and New Zealand; and Europe and Northern Africa. The results of the experiment showed that COVID-19 impacted the life expectancy of all regions of the world and HIV/AIDS did as well but only in Sub-Saharan Africa. The other pandemics did not have any significant impact. Due to the results of the experiment, the null hypothesis can be rejected for the HIV/AIDS epidemic and the COVID-19 pandemic.

Ashna Sureshkumar -The Effect of Petroleum Jelly on Trans epidermal Water Loss
Mills E Godwin High School

The aim of this study was to examine the effect of various types of petroleum jelly on trans epidermal water loss (TEWL). Chronic skin diseases are prevalent and can be triggered by a range of factors such as chemotherapy, environmental conditions, and genetics. In this experiment, petri dishes containing agar jelly were treated with Vaseline, Aquaphor, CeraVe, or no petroleum jelly. Humidity and temperature were monitored every 24 hours for 2 days and

TEWL was calculated. It was hypothesized that Aquaphor would result in the greatest reduction in TEWL. Results showed that Aquaphor reduced TEWL by an average of 0.6 more than CeraVe and Vaseline. A t-test was conducted, and the data was found to be significant for four of the comparison groups, but not statistically significant for the remaining two groups. These findings support the research hypothesis and suggest that the main ingredient in Aquaphor, petrolatum, and its humectant properties (due to ingredients such as panthenol, bisabol, and glycerin) may contribute to its ability to improve skin barrier function and retain moisture. Further research could involve testing the effects of these petroleum jellies on human skin or comparing their effectiveness to other moisturizers.

Andy Tawney- Repeat Lengths of RS3 Alleles Associated with the Rate of Health-Related Risky Behavior in Young Adults
Southwest Virginia Governor's School

Risky behaviors such as outbursts of aggression, excessive rule-breaking, and unhealthy eating habits can have dire consequences. Young adults can be especially vulnerable to this. Though their upbringing may play a role in this, other research has shown genetics may be involved too. RS3 alleles have been associated with more social and kind behaviors in mammals whereas shorter RS3 alleles are not. Therefore, the goal of this study was to see if there is an association between risky behaviors and the lengths of RS3 alleles. Ten young adults were selected from the Southwest Virginia area; they were asked to complete an IRB-approved modified Adolescent Health-Risk Behavior Inventory (AHRBI) and to provide a saliva sample. RS3 was amplified using PCR, and gel electrophoresis was used to determine individual genotypes. RS3 repeat lengths and AHRBI scores were compared with a Student T-test using JMP. It was found that the group with shorter RS3 alleles had significantly ($p=0.0057$) higher AHRBI scores (56.5 ± 0.5) than the group with longer RS3 alleles (42.875 ± 4.0), which suggests that shorter RS3 repeats are associated with more risky health-related behaviors in young adults. Additional studies of these genetic polymorphisms may be useful to support genetic screenings and interventions at a young age to prevent potentially harmful behavior. It will be important to examine these initial results with a larger population and to determine whether the same trend is present with other risky behaviors beyond those affecting health.

Nivriti Vanga - Differential De Novo Sphingolipid Synthesis Protein Expression in NPC1 Mouse Brain Tissue
Mills E Godwin High School

Niemann-Pick type C1 (NPC1) is a protein controlling transportation of lipids from lysosomes. Genetic mutations formed in this protein can lead to the autosomal-recessive disorder, NPC1. Commonly found in children, this disease results in neurodegeneration, dementia, ataxia, and more leading to reduced longevity. One characteristic of this disorder is the increase in production of sphingolipids in the de-novo sphingolipid metabolic pathway, found in the

endoplasmic reticulum. Studying the specific protein quantifications of sphingolipids and protein regulators can help further advance knowledge of the disease on a microscopic level and the origin of the disease in this metabolic pathway. This would lead way for further studies and may aid in the creation of medications/drugs to combat NPC. In this study, western blots were used to observe protein quantifications of NPC1, ORMDL sphingolipid biosynthesis regulator, and serine palmitoyltransferase (SPT) in both knockout NPC mice and wildtype mice. The proteins were then compared among the mice with and without the disease to see if it impacted the specific quantities of the proteins in the mice. The hypothesis formed was, if NPC1 knockout mice and wildtype mouse brain tissue are run through a western blot to detect ORMDL, SPTLC2, and NPC1, then the knockout mice will have no NPC1 proteins, an increase in SPTLC2 protein, and a decrease in ORMDL proteins in comparison to the wildtype mice. The results proved the hypothesis to be incorrect and there was a general trend between the wildtype mice and the knockout mice.

Vimridh Vasudev -The Effect of Varying pH using Betaine HCl on the Digestive Catalytic Assimilation of a Gastric Acid Solution
Mills E Godwin High School

The purpose of this experiment was to understand the effects of gastric acid on digestive efficiency. Even when food consumption is sufficient, inadequate digestion and/or absorption of macronutrients, micronutrients, and other dietary components can lead to insufficient intake of crucial nutrients. Although nutritional deficiencies are challenging to identify, these impacts encompass a wide range of clinical and subclinical signs and symptoms, such as the typical gastrointestinal symptoms connected to malabsorption. For this experiment, food samples were dissolved in a gastric acid solution with pH values of 1, 3, 5, and 7, and time taken for food to cease bubbling and visually separate into proteins and carbohydrates was quantified in seconds. If food did not begin to digest within thirty minutes, the timer was stopped, and 1800 seconds was recorded. Food assimilated quicker as pH value decreased, supporting the hypothesis that trials with a pH value of 1 would digest the fastest. Time taken for food to dissolve was compared between trials, and t-tests were performed on the results. All data was determined to be statistically significant at alpha-value of 0.001, implying that results were caused by the independent variable and not due to chance or error. It is believed that the results are due to the fact that the lower acidity the stomach acid is, its efficacy at digesting food in humans increases, is because it is better able to break down proteins and other complex molecules, which allows the body to absorb the nutrients from the food more efficiently.

Emily Wesley - The Effect of Different Amounts of Caffeine Consumption on the Amount and Quality of Sleep
Central Virginia Governor's School

Many different outlying factors can affect your quality and amount of sleep. One of these factors is caffeine. Through

testing, it becomes possible to discover the relationship between the two. By analyzing sleep patterns between different levels of caffeine intake, we can determine to what extent they affect each other. Using surveys and the PSQI (Pittsburgh Sleep Quality Index), it became possible to obtain levels of caffeine intake as well as levels of sleep quality. An ANOVA was run to determine a significance between the different levels and the sleep proficiency scores. With a P-Value of 0.02, it was lower than the alpha of 0.05, meaning a post-hoc test was run. This test showed significance in between the lowest and medium group, as well as the high and medium group. However, the research hypothesis was not supported. Results showed that the group who consumed a medium amount of caffeine had the best sleep quality while people consuming small amounts had the worst sleep quality. This study showed that sleep and caffeine do have a relationship, but not aren't entirely inverse.

Alejandra Wittman -The Effect of Various Types of Padding Materials, inside a Baseball Helmet, on Percentage of Times a Simulated Brain Ruptures Inside the Helmet, and on Force of Impact Measured Inside the Helmet
Clover Hill High School

The purpose of this experiment was to determine whether no padding, foam padding, styrofoam padding, sponge padding, or gel padding would have the lowest percentage of simulated brain ruptures inside the baseball helmet, and lowest force of impact measured inside the helmet (g). The hypothesis was that the helmet trials with no padding would cause the highest percentage of simulated brain ruptures inside the helmet, and the highest force of impact, and the helmet trials with foam padding would cause the lowest percentage of simulated brain ruptures inside the helmet, and the lowest force of impact. In order to test the hypothesis, a 2.2 kg kettlebell was swung from a stand into a plastic skull model which surrounded a water balloon and an accelerometer. A helmet with various padding materials depending on the trial was placed upon the plastic skull model and the force of impact and rupture of the simulated brain water balloon was tested. The foam allowed for the lowest force of impact compared to no padding, and the sponge had the second lowest force of impact. The brain ruptures occurred at similar rates, with foam padding having a slightly lower rate than the other padding materials and the control. The null hypothesis said that the various types of padding materials inside a baseball/softball helmet would not affect the percentage of times a simulated brain ruptured inside the helmet, or the force of impact measured inside the helmet (g) or that all the materials tested would yield equal results, and because the p value of the experiment was 0.000266, the null hypothesis was rejected. The research hypothesis was partially supported because the foam padding had the lowest force of impact, and the no padding had the highest force of impact. However, it was not supported in that the foam padding also had the most brain ruptures, and the no padding helmet had the second highest amount of unruptured brains.

Yeeun Lee -The Impact of Binge Ethanol During Adolescence on Myelin Related Gene Expression
Deep Run High School

Adolescents tend to consume alcohol in binges. The earlier one begins to drink, the higher risk they have of developing an alcohol use disorder later in life. Brain development is ongoing throughout adolescence, and consuming ethanol in during this stage of life can have a long-term negative impact. Specifically, decreases in myelin and white matter in the frontal cortex have been shown following binge ethanol in adolescence, which may cause cognitive deficits. In this study, expression levels of different genes were measured to detect if adolescent ethanol treatment had an impact on myelin-related gene expression. mRNA expression level of genes important to the maturation of oligodendrocytes, which form myelin sheaths, were measured. We hypothesized that ethanol treatment would decrease expression of these genes and therefore negatively affect myelin and the maturation of oligodendrocytes. Ethanol (4 g/kg) or water was provided to adolescent male and female mice during adolescence (postnatal day 29-42). Four hours and twenty-four hours after their last dose, prefrontal cortex tissue was collected. Quantitative reverse transcriptase PCR (qRT-PCR) was utilized to determine the expression level of the myelin-related genes. This study shows the immediate and lasting consequences of binge alcohol in adolescence on genes that regulate myelin development in the prefrontal cortex.

Microbiology & Cell Biology A (HS MCB-A)

First Place

Ann M. Hancock Cellular Biology Award

Nicola Beaumont - The Effect of Salinity on the Growth of Chlorella

H-B Woodlawn Secondary Program

Algae can be used to produce biofuel, an environmentally friendly alternative to fossil fuels. However, high production costs have limited its use, making it imperative to find ways to reduce costs to increase its viability. One potential solution is to cultivate algae in brackish groundwater or wastewater that already contains needed nutrients, but these options can have higher salinity than freshwater. The purpose of this experiment was therefore to explore the effects of salinity on the growth of algae. Chlorella was grown for two weeks in solutions with varying NaCl concentrations (the control 0%, 0.6%, 1.3%, 1.9%, and 2.5% NaCl), with four trials run for each salinity level. Chlorella's growth was proxied by the optical density of the Chlorella solutions when tested with a colorimeter set to 635 nm. Daily measurements were made to test the hypothesis that high salinity would negatively impact Chlorella's growth. The data collected showed a steady reduction in algae growth as the salt concentration increased to 1.9%. The control with 0% salinity had the strongest growth, while algal population growth with 0.6% and 1.3% salinity were only 65% and 37% of the control's growth respectively. In salt concentrations of 1.9% and 2.5%, Chlorella populations ultimately decreased by the end of the 14 days. An ANOVA analysis found the differences in growth to be statistically significant. These results are useful because they show that there is potential for using moderately brackish groundwater and wastewater to cultivate Chlorella for biofuel production.

Second Place

Jason Chen - Got Milk? Comparing the Acid Production of *Bifidobacterium infantis* when Grown in Different Milks

Central Virginia Governor's School

The purpose of this study was to determine if different types of milk affected the growth and acid production of *Bifidobacterium infantis*, a powerful probiotic crucial for human development. There was a total of six groups that consisted of 100 mL of inoculated whole milk, lactose-free milk, formula, and uninoculated control groups of each type of milk. The experimental groups were inoculated by pouring hydrated *B. infantis* probiotic powder into the different milks. All groups were incubated aerobically for 24 hours at 37°C and diluted in 10% solutions. After incubation, the pH of each sample was tested with a pH probe over eight trials. The statistical significance of the experiment was

calculated using two single-factor ANOVAs, the first with both control and experimental data and the latter with just experimental data. Their respective p-values of 1.01×10^{-20} and 1.05×10^{-3} ($\alpha = .05$) indicated that the data were statistically significant for two out of three of the experimental groups and the remaining group, whole milk, was not. Using the significant results from the two ANOVAs, post-hoc Tukey tests were performed, and significant differences were found between each experimental group except between the inoculated formula and whole milk groups. These results confirmed that my research hypothesis that whole milk would allow for the best growth of *B. infantis* was not supported. The results suggested that lactose-free milk and formula are well-suited media for *B. infantis* to thrive in and have great potential to become convenient methods of obtaining essential probiotics.

Third Place

Emma Baldwin -The Effects of Aminoglycoside & Beta-Lactam Antibiotics on *S. marcescens*
Roanoke Valley Governor's School

Serratia marcescens causes biofilms in catheters leading to urinary tract infections, this type of bacteria can also cause illness such as respiratory infections; therefore, to improve patient outcomes the effect of different types of antibiotic treatments were tested. This experiment sought to test the effect of antipseudomonal beta-lactam and aminoglycosides when used simultaneously to provide optimal care. Considering this, in this experiment Gentamicin (aminoglycoside) and Amoxicillin (beta-lactam) were used. In other literature, Chloramphenicol was used to inhibit *S. marcescens* biofilms and was successful. Consequently, in this experiment Chloramphenicol was used for comparison to typical use because it is a potent antibiotic. For this experiment, the hypothesis was: *S. marcescens* would be inhibited by Amoxicillin paired with Gentamicin and yield a larger zone of inhibition (ZOI) than if used separately. However, Chloramphenicol ought to yield the largest ZOI. After 24 and 48 hours ZOIs were measured and despite prior literature findings, Gentamicin was seen to have the largest ZOI (25.25 mm) after 24-hours (ANOVA, p-value < .001). Amoxicillin and Gentamicin for comparison had a ZOI of 22.34 mm after 24-hours. Amoxicillin had no zones of inhibition. Given these results, Gentamicin used alone yielded the premier outcome, leading to evidence to the contrary of typical clinical treatment of beta-lactam with aminoglycoside antibiotics. This finding is staggering considering that Gentamicin was used with a smaller dosage than the other antibiotics. This experiment combined a beta-lactam and aminoglycoside antibiotic; however, further research should be conducted to test other combinations of these antibiotic types.

Honorable Mention

Emma Ackleson -The Effect of Medical Scrub Compositions on the Conduciveness for Bacterial Growth
Washington-Liberty High School

This experiment was conducted to see which fabric composition of medical scrubs is the most resistant to bacterial

growth. The hypothesis for this experiment was if *Staphylococcus epidermidis* bacteria was placed on different scrub material compositions (100% cotton, 100% polyester, 50% polyester-50% cotton, and 100% rayon), then the 100% cotton material will be the least conducive for growth because it is woven more loosely than synthetic materials, containing more pores. Bacteria thrives on non-porous materials. Bacteria on porous materials are absorbed and trapped, thus then struggling to replicate. Sterile scrub cloth samples were placed in sterile Petri dishes and inoculated with *S. epidermidis* and were placed in room temperature for 24 hours. The cloth samples were then swabbed with sterile swabs and used to inoculate sterile agar Petri dishes. These inoculated Petri dishes were then placed in room temperature for another 24 hours. The colony forming units (CFUs) were then counted. The scrub sample with the least CFUs after 24 hours was the 100% cotton scrub sample with a mean CFU of 0.19. The scrub sample with the highest number of CFUs was 100% polyester, with a mean CFU of 417.75. Results were then compiled in a data table and graph. Standard deviations were calculated as well as an ANOVA test and t-tests. A p-value of 9.4917×10^{-10} was calculated via the ANOVA test. The t-test between the 50% polyester - 50% cotton, and polyester groups ran with a p-value of 2.907455×10^{-2} . Results were statistically significant for both tests. The data from the experiment supports the hypothesis. The null hypothesis was rejected. This experiment could be improved by testing different additional scrub materials or testing a larger experimental group.

Honorable Mention

Helen Hanke -The effect of mouthwash alternatives on the zone of inhibition of *Staphylococcus salivarius*
Washington-Liberty High School

The purpose of this experiment was to study the effects of diverse mouthwashes on the growth of *Staphylococcus salivarius*. The hypothesis stated that if Listerine antiseptic mouthwash was used, then the *Staphylococcus salivarius* will have the least growth because it has been proven through tests to have the power to kill all sorts of germs, but specifically those leading to gum and mouth diseases, and reduces plaque by 52% more than just brushing and flossing. The hypothesis was not supported by the data because Listerine antiseptic mouthwash averaged a zone of inhibition of 2.7 cm. Hydrogen peroxide measured 4.1 cm, Apple cider vinegar was 1.8 cm and distilled water was 0 cm. An ANOVA test was done to determine if a statistically significant difference existed among the means for the groups. The calculated p-value was 2.73×10^{-49} , which is less than the critical value of 0.05 meaning the data was statistically significant. T-tests were done between each of the IV levels determining that each of them was significant. This means the null hypothesis: If *Streptococcus salivarius* is treated with different mouthwash alternatives/mouthwashes, there will be no difference in the zone of inhibition between groups, was not accepted.

Honorable Mention

Andrew Dang -The Effect of Water Concentration on Bacteria Growth
Mills E Godwin High School

Kitchen sponges have been a major source of bacterial contamination due to their ability to retain moisture and food residue inside themselves. These contaminated sponges, if not cleaned or stored properly, are capable of easily spreading bacterial infections and foodborne pathogens. The purpose of the study was to investigate the effects of different levels of moisture on the growth of bacteria in household sponges. It was hypothesized that if a sponge's water content was lower after each use, then fewer bacteria would grow inside the sponge. The control for the experiment was 100% water concentration because the purpose of the experiment was to find out if lower concentrations resulted in fewer bacteria and 100% is the highest possible concentration. After using four different sponges, with each used once a day for a week, small pieces of the sponges were cut, streaked onto agar plates, and incubated. The number of colonies was counted, and the results showed that a higher concentration of water resulted in a higher number of bacterial colonies. At a level of significance of 0.05, the t-tests comparing the three different concentrations to the control showed that the calculated t-values for all three tests were greater than the table values, indicating that the data was statistically significant and supported the research hypothesis. This occurred as a result of the food residue and excess water trapped inside the sponge, which created an ideal environment for the bacteria to thrive.

Nadia Hassen -The Effects of Toothpaste on Bacterial Growth
Washington-Liberty High School

This experiment tested, which type of toothpaste removes the most Escherichia coli K-12 from the mouth. The two types of toothpaste tested were fluoride toothpaste and fluoride-free toothpaste. The independent variable in this experiment was the different types of toothpaste used. Specifically, the brand of the toothpaste that was tested was Crest, Colgate, Toms, and Burt's Bee, while the control group had only bacteria present. The dependent variable that will be measured in this experiment is which type of toothpaste can remove the most bacteria. It was hypothesized that if fluoride toothpaste and fluoride-free toothpaste are compared to see which one removes the most bacteria, then fluoride toothpaste will be victorious. The average growth of the control group was no growth, Crest with 0.5 centimeters, Colgate with 0.2 centimeters, Burt's Bee with 1.1 centimeters, and Toms with 0.8. The experimental growth that had prevented the most growth of bacteria was Burt's Bee, as it kept away the most bacteria. The next independent variable with the highest prevention of growth was Toms, as it was able to keep the bacteria away, but was not as effective as Burt's Bee. Crest had a very low level of prevention, as bacteria continued to form when present. Lastly, Colgate had the lowest level of prevention with 0.2 centimeters and had many petri dishes that had bacteria growing all around the small paper disk. The results of the standard deviation differed from the average growth, as Toms was seen to have the highest deviation instead of Burt's Bee. Burt's Bee and Crest had the same numerical value for the standard deviation and Colgate once again had the lowest value. The p-value between all the experimental groups was 0.938853535. Since the p-value was not less than 0.05, it proves that the results were not significantly different and that the null hypothesis cannot be rejected. The only test that was conducted was an ANOVA test.

Ria Chandran -The Effect of Various Cleansers on Acne (*Escherichia coli*)
Mills E Godwin High School

The purpose of this experiment was to determine the effects of various cleansers on acne comedones. Recently, acne has been a progressively predominant issue and CeraVe Foaming Facial Cleanser, Olay Cleanse Gentle Foaming Cleanser, and Aveeno Positively Radiant Skin Brightening Scrub were the most purchased cleansers to treat acne prone skin. *Escherichia coli* was treated with 20 μ L of CeraVe Cleanser, Olay Cleanser, or Aveeno Scrub. The bacteria were incubated for forty-eight hours and the diameter of the zone of inhibition was measured in millimeters. The control that was used in the experiment was water. A research hypothesis was formulated that if various acne products were tested on *Escherichia coli*, then Aveeno Positively Radiant Skin Brightening Scrub will have the best effect on the bacteria. The results revealed that the Aveeno Positively Radiant Skin Brightening Scrub impacted the bacteria more than the water, Olay, and CeraVe applications. A t-test was conducted on the data, and it revealed that the data was significant for water vs Olay, water vs Aveeno, and CeraVe vs Aveeno, but not significant for water vs CeraVe, CeraVe vs Olay, and Olay vs Aveeno. The results supported the research hypothesis. It is believed that the results are due to the zone of inhibition being the greatest based on the tests performed using Aveeno Positively Radiant Skin Brightening Scrub. This research could lead to further studies that investigate Neutrogena Oil-Free Acne Wash on acne and how various oil free cleansers affect the bacteria.

Carson Gilmore- Effect of Conjugated Linoleic Acid on Structure of Skeletal Muscle
Blacksburg High School

It has previously been shown that supplementation of conjugated linoleic acid increases the amount of force mice put out in an in vivo torque frequency test. The reason for this is unknown but might be explained through examination of skeletal muscle from the supplemented mice. This research aims to explore the nuclei content and extracellular matrix of quadricep tissue from supplemented mice, with the goal of determining why CLA supplementation leads to increased force. Upon discovering the reason, the body of knowledge surrounding CLA increases, and it further has potential to be supplemented by humans. The desired variables were studied through immunohistochemistry, using an anti-laminin antibody to reveal ECM content, and counterstaining with DAPI to show nuclei. After imaging the treated muscle sections, the following results were determined: Tissue treated with CLA showed a similar average nucleus count in 200x200 micron sections to that of untreated muscle (66 to 65 respectively). Tissue from supplemented mice contained more ECM. The increase in ECM could potentially be the reason for increased force, given that it plays a large role in producing effective/efficient muscle contractions. This means that an increase in ECM could lead to either stronger contractions, and/or more contractions in a given movement. Although this seems to explain the connection between CLA and increased strength, these results were taken from two mice, and can't yet be proven significant. More tests are currently being run to determine whether or not CLA has a significant effect on ECM content.

Cedrick Dimaranan - Redesigning the Kirby-Bauer Agar Standards to Improve the Efficacy of Antibiotic Detection
Ocean Lakes High School

Current methods to study environmental antibiotic pollution, an emerging cause of antibiotic resistance, possess a restricted scope of detection and are resource-intensive, limiting their prevalence. New, more accessible means of studying antibiotic pollution are therefore necessary. Accordingly, this ongoing research explores the effect of changing both the type and depth of agar used on the sensitivity of the Kirby-Bauer disc diffusion test to determine if the test could be rendered viable to detect antibiotics in environmental samples. Based on past literature, the hypothesis for this research is that if nutrient agar were used in place of Mueller-Hinton agar and if lower depths of agar were used in the Kirby-Bauer test, then the sensitivity of the test would increase. To test the hypothesis, two types of agars, nutrient agar and Mueller-Hinton agar, were prepared at various thickness levels. The Kirby-Bauer test was then performed on these prepared agar plates using erythromycin, amoxicillin-clavulanic acid, and levofloxacin antibiotic discs and K-12 *Escherichia coli*. Zone diameters produced by each antibiotic on each agar were subsequently graphed against agar depth to create predictive least-squares regression lines. The results indicated that the degree to which the test's sensitivity changed through modifying the agar type and depth depended on the antibiotic used; however, two-millimeter agar generally increased the sensitivity of the test and would likely be best for detecting environmental antibiotics. Future research would involve more antibiotics and agar types to further ascertain how the Kirby-Bauer test responds to changes in its agar standards.

Claire Goody -The Effect of the Type of Mouthwash on the Inhibition of *Escherichia coli*. (*E coli*)
Washington-Liberty High School

Mouthwash is an oral product that can help reduce the number of bacteria in the mouth. The rapid transmission of Covid-19 across the globe led to measures taken to control the spread of the virus. One of these measures included using mouthwash, which reduces the chance of Covid-19 being spread orally since its ingredients help kill off viruses (including Covid-19) found in saliva. The purpose of this study was to determine the effectiveness of different types of mouthwash at inhibiting the growth of *Escherichia coli*. The types of mouthwash used in the experiment were Listerine® (alcoholic), Crest® (non-alcoholic), and Tom's (all natural), while distilled water was the control. It was hypothesized that Listerine® would be the most effective at inhibiting the growth of *Escherichia coli* since alcoholic mouthwashes contain essential oils that have shown to be the most effective at reducing the number of bacteria in the mouth. The experiment was conducted over four days, which included preparing the agar plates, inoculating the plates with the *Escherichia coli* bacteria, and treating them with each type of mouthwash (and the control). The mean zone of inhibition was calculated after 68 hours for all groups. The results showed that Crest® was the most effective at inhibiting the growth of *Escherichia coli*, with a mean zone of inhibition of 1.45 centimeters. Listerine® and the control had mean zones of inhibitions of 1.25 and 1.18 centimeters respectively. On the other hand, Tom's was the least effective at

inhibiting the growth of *Escherichia coli*, with a mean zone of inhibition of 0.58 centimeters. The original hypothesis was rejected, although the null hypothesis was partially accepted since there was no statistical significance between some of the groups.

Anna Brodsky -The Effect of Sound Frequency on the Growth of *E. coli* K-12
Washington-Liberty High School

Combating bacterial infections is one of the most important issues in medicine today; more effective than treating an existing infection, though, is preventing bacterial contamination in the first place. One proposed method of surface decontamination is using sound waves to disrupt bacterial colonies. However, little research has been done into the optimal sound frequency for sterilizing different species of bacteria. This project hypothesized that *E. coli* K-12 bacterial inhibition would be greatest in the presence of sound with a frequency of 10,000 Hertz, while the bacterial growth rate would be significantly higher when grown in lower-frequency sound waves (10 Hz or 1,000 Hz) or in silence. The original sample of *E. coli* K-12 was diluted in nutrient broth and subjected to sound for 10 minutes before being plated and allowed to grow overnight. The number of colonies present on the agar plate after a day of growth was used to calculate the original concentration of bacteria in each sample. The sample of *E. coli* K-12 grown in the presence of sound at 10 Hz was found to experience the least growth (with a total of 416 colonies/plate, on average), while the bacteria grown in silence were found to be much denser (7,280 colonies/plate), more than 18 times as concentrated. The samples of *E. coli* k-12 grown in the presence of 1,000 Hz and 10,000 Hz were both found to have more bacterial growth than bacteria grown in silence, with 3.6 times and 4.7 times greater concentration, respectively. An ANOVA test was used to determine the statistical significance of this project's data, and with a low p-value of 1.4043×10^{-10} , the null hypothesis, that sound frequency does not affect the growth of *E. coli* K-12, was rejected.

Microbiology & Cell Biology B (HS MCB-B)

First Place

Ann M. Hancock Cellular Biology Award

Kriesh Tivare - Effect of Switching Magnetic Fields on the Growth Behaviors of Gram-Negative *Escherichia coli* Bacteria.

Langley High School

Magnetic fields have various applications, including power transmission and electricity generation, but their potential medical uses are yet to be fully explored. The impact of magnetic fields on biological organisms has not been widely studied, but investigating this could lead to innovative medical applications. In this study, the effect of "switching" magnetic fields on the growth activity of *Escherichia coli* (K-12 strain) was investigated by exposing liquid microbial cultures to a square wave magnetic field with a frequency of 50 Hz and a magnetic intensity range of 200-3000 μ T at a constant temperature of 37°C for periods of 2-17 hours. A ferromagnetic container was used to protect the control inoculum from magnetic field exposure. After a 28-hour incubation period, the exposed and control samples were analyzed for their Colony Forming Units (CFUs). The results revealed that the switching magnetic field had a significant impact on the growth behavior of *E. coli* (K-12 strain), stimulating bacterial colonies by up to 13% and inhibiting them by up to 38%. Further research in this area could lead to the development of more efficient biotechnology and life-saving treatments for bacterial diseases.

Second Place

Nadia Lach-Hab – Effect of *E. coli* Treatment Type on *E. coli* Zone of Inhibition

Washington-Liberty High School

The purpose of this experiment was to determine which treatment type of *E. coli* was most effective at limiting the growth of the *E. coli* K-12 bacteria. There were three different treatment types: vitamin C, ampicillin, and a combination of the two. Results were measured using the zone of inhibition of the *E. coli* bacteria. It was hypothesized that the trials containing a combination of vitamin C and ampicillin would be most effective at limiting the growth of *E. coli*, therefore increasing the zone of inhibition. This was hypothesized because previous studies have proved both an ampicillin, an antibiotic that derived from penicillin, and vitamin C, a nutrient, were effective at limiting the growth of *E. coli*. This hypothesis was supported, however, the trials that contained only ampicillin were equally as effective, both were 100% effective: there was no growth of bacteria. Vitamin C was 35% effective on average at limiting growth, and the average

zone of inhibition was 7.38 mm. Adding on to the previous statement, all three treatment types were more effective at limiting the growth of *E. coli* than the control. This data was statistically significant, as all of the treatment types had an effect on the zone of inhibition of the *E. coli*. This data suggests that using ampicillin or a smaller dose of ampicillin and a smaller dose of vitamin C is 100% effective against the growth of *E. coli* bacteria. The data and conclusions reached were mostly alike to similar studies done in the past.

Third Place

Daisy Maxwell -Evaluating the Potential of Herb-derived Essential Oils as Natural Antimicrobials
Washington-Liberty High School

The purpose of this experiment was to determine whether herb-derived essential oils have antimicrobial capabilities. Having such capabilities would make them useful as a natural alternative to antimicrobial drugs, which is important due to the rising impacts of drug-resistant infections. The experiment was conducted by testing the effect of essential oils made from ginger, oregano, thyme, and garlic upon the growth of *Escherichia coli*. All four types of essential oil created zones of inhibition, which shows that herb-derived essential oils do have significant potential as natural antimicrobials. It was hypothesized that the garlic essential oil would inhibit the growth of the bacteria the most due to previous research that found that garlic's constituent allicin has a strong inhibitory effect on microbial growth because of its chemical reaction with the thiol groups in enzymes. However, the results showed that the thyme essential oil had the greatest rates of inhibition. Although the oregano essential oil had a smaller mean zone of inhibition than thyme, their difference was not proven to be statistically significant. Garlic essential oil caused the third largest mean zone of inhibition, and ginger created the smallest. The success of thyme- and oregano-derived essential oils shows that they have particular potential as forms of natural antimicrobials. Additionally, their antimicrobial properties both come, at least in part, from the constituent thymol, so it was concluded that thymol has significant prospective in the search for alternatives to antimicrobial drugs.

Honorable Mention

Alexandra Nguyen - The Effect of SPF Moisturizer on *S. epidermidis* Growth
Mills E Godwin High School

The experiment's purpose was to determine if SPF moisturizers encourage or inhibit *S. epidermidis* growth. *S. epidermidis* is a common strand of bacteria present in the skin's microbiota. The chemicals present in cosmetics, such as SPF moisturizers, may alter the microbiota's biodiversity. Skin is an important indicator of human health; alternation may lead to permanent damage, diseases, or infections. The experiment's results can be used as a base to figure out which cosmetic products are safe for the human skin. The hypothesis that CeraVe would grow the lowest number of

bacteria was accepted. Nutrient agar plates that received no SPF moisturizer were classified as the control. Nutrient agar plates containing *S. epidermidis* soaked paper discs in each quadrant and SPF moisturizers were incubated in 37°C for forty-eight hours. Each moisturizer had twenty-five quadrants. After the incubation period, the bacterial growth from the discs were measured in millimeters. CeraVe presented the strongest inhibition towards *S. epidermidis* growth, as its mean growth was 0.016 mm. T-test calculations were used, and when results were compared, all independent variable levels had a value less than the t-table's critical value. This indicated that the data was statistically significant and not due to chance. Multiple scientists have studied the skin's microbiota and findings show that control groups tend to produce the most bacterial growth. The experiment could have had errors of minimized results which can be resolved by time-management. To further extend the research, other cosmetics can be tested for bacterial growth.

Honorable Mention

Josephine Kicklighter - Comparing the Effectiveness of Herbal Remedies on the Growth of *Streptococcus gallolyticus*
Central Virginia Governor's School

The purpose of this study was to determine whether plant-based treatment was effective in inhibiting the growth of *Streptococcus gallolyticus*. *Achillea millefolium*, *Calendula officinalis*, and *Chelidonium majus* were used to make essential oils and ethanol extracts. Essential oils were prepared by soaking 4oz of each herb in jars filled with sunflower oil for three weeks. Ethanol extracts were prepared by macerating each of the herbs in an 80% ethanol solution in a ratio of 10:1 (v/w) (ethanol to herbs) for 48 hours. 500 mL of ethanol was combined with 50g of each herb to create three distinct solutions. Afterward, the solutions were filtered and left to sit at room temperature for three days to evaporate the excess ethanol. Eight trials were conducted by placing filter discs soaked in each independent variable and a control (dH₂O) on tryptic soy agar petri dishes coated with *S. gallolyticus*. The petri dishes were left to incubate for 24 hours at 37°C. Afterward, the zones of inhibition were measured in mm. Single-factor ANOVA tests analyzing the means of the zones of inhibition determined significance (p-values = 2.6×10^{-9} , 2.775×10^{-7} , $\alpha = .05$). A Tukey test (Qt = 4.39 and Dmin = 4.106) determined where the significance was held. All groups were found to be statistically significantly different from the control. The results suggested that both ethanol extracts and essential oils possess antimicrobial properties and could prove crucial in controlling the spread of antibiotic-resistant diseases.

Honorable Mention

Audrey Hunter -The Effect of Various Types of Disinfectants, Applied to Bacterial Samples, on the Portion of the Plate Covered by Growth, Over Time
Clover Hill High School

This experiment was conducted to determine the most effective disinfectant when applied to inoculated agar plates

which were then incubated. Knowing which disinfectants work best allows people to prevent disease transmission and potentially save lives. Currently, with SARS-CoV-2 and other pathogens posing an active threat, proper sterilization is a serious concern. The disinfectants tested were water (control), Clorox spray, 70% ethanol alcohol, and Purell hand sanitizer. Samples were collected from school desks with cotton swabs, then applied to 120 agar plates. Each disinfectant was applied to 30 plates, which were then placed in an incubator for 93 hours. The plates were sorted into categories based on the amount of visible growth. A Chi Square test was conducted to determine the statistical significance of the data, and it was able to conclude that the data was statistically significant. The median amount of growth was 1-10% for the control group (water), 0% for 70% ethanol, 1-10% for Purell, and 0% for Clorox. No plates treated with Clorox had any visible growth. The Clorox spray was the only disinfectant that contained hypochlorite bleach, which was also found to be effective in other studies. The null hypothesis was rejected, and the data supported the research hypothesis, which was that when applied to inoculated agar plates, Clorox would inhibit the most growth.

Tyler Hinton -The Effect of Various Disinfectant Methods on the Decline of *Escherichia coli*
Central Virginia Governor's School

Escherichia coli is a common gram-negative bacterium that can lead to serious illnesses and health problems. The purpose of this study was to determine what method of disinfection (UV-C light, Clorox, NanoTouch, and no treatment) was most effective in killing *Escherichia coli*. Through the use of aseptic technique, serial dilutions, and spread-plate method, this experiment helped to define an answer to the purpose. The use of aseptic technique helped to ensure cleanliness and sterility throughout the experiment, while the serial dilutions (*E. coli* nutrient broth dilutions of 10⁻⁵ and 10⁻⁶) helped to clarify the numerical data that resulted from the treatment methods. The spread-plate method was used to spread the treated *E. coli* nutrient broth onto a nutrient agar petri dish to show the colony forming units that grew to show the statistical response to the treatment. A single-factor ANOVA test was run to determine statistical difference and output a p-value of 8.3x10⁻⁵ (alpha = .05). The post-hoc Tukey test that followed showed statistically significant differences between both the Clorox and Phonesoap when compared to the control and NanoTouch, and also between the control and Nanotouch themselves. The research hypothesis, which claimed that the PhoneSoap group would be the most effective, was partially supported, as it shared the title with Clorox as the most effective in killing the *Escherichia coli*. This experiment can be very beneficial to the world of microorganisms and how to effectively rid surfaces of these harmful bacteria.

Nath Sattwik -The Effect of Different Compounds on Planaria Regeneration
Mills E Godwin High School

The Purpose of this experiment was to determine the effects of Chondroitinase ABC (ChABC), taurine, and ibuprofen

on the regeneration of planaria. Every year, around 5.4 million people end paralyzed due to spinal cord injuries (SCIs). SCIs are due to glial scarring. Glial scarring is scarring on CNS cells that prevents regeneration. If glial scarring can be prevented, people suffering from SCIs can regain some previously lost functions. The hypothesis was, if a concentration of Chondroitinase ABC (ChABC) is given to planaria, they will be able to regenerate at the highest speed. Three 0.5% solutions were made, one with each level of IV. A fourth solution was made with only water, and it served as the control to have a baseline of how fast planaria regenerate on average. A group of 25 planaria was put into each solution and total growth was calculated. The results were graphed, and a t-test was performed. The mean for ChABC, taurine, ibuprofen, and the control were 7.328, 6.9, 5.036, and 6.132 respectively. Most of the data was within 2 SDs away from the mean so there were few outliers. The results of the t-tests for ChABC, taurine, and ibuprofen were 19.708, 11.135, and 25.259 respectively. Since the data was higher than the table value of 3.505, it was significant. The results for ChABC and taurine were due to known regenerative properties. The results for ibuprofen were most likely due to human errors. Future experiments can be conducted on human cells instead of planaria.

Samyukta Iyer -The Effect of Natural Antibiotics on the Inhibition of *Escherichia coli* Growth
Mills E Godwin High School

Natural antibiotics are highly effective in inhibiting bacterial growth. They are the best alternative in medicine as resistance to synthetic drugs is increasing due to their rapid consumption. The purpose of this experiment was to assess the efficacy of various natural antibiotics, such as honey, clove, oregano, and garlic, on inhibiting *Escherichia coli* growth. Mueller Hinton agar plates were swabbed with *E. coli* K-12 and the antibiotic-dipped discs were placed onto the agar. After incubation for 24 hours at 37°C, the zone of inhibition was measured in millimeters. A control wasn't used in experimentation, but the negative control, which was a plate promoting bacterial growth, was used for data analysis. It was hypothesized that honey would have the largest inhibition zone as its active compounds, such as hydrogen peroxide, and defensin-1, function jointly to prevent growth. The results showed that all the natural antibiotics positively affected the inhibition zone of *E. coli*. The mean was the highest for honey, meaning honey was the most effective in inhibiting growth. A t-test was performed, and it was revealed that the data is statistically significant. Therefore, the results did support the research hypothesis. The results were due to active compounds and antibacterial enzymes in the natural antibiotics that caused an inhibition of bacterial growth. These molecules and proteins interact with the bacteria's plasma membrane and DNA by damaging it. The experiment could be further expanded by comparing the efficacy of synthetic and natural antibiotics.

Keiera Kim -The Effect of Polymer Type on Biodegradation Success by the Fungus *Aspergillus flavus*
Maggie L. Walker Governor's School for Government and International Studies

Millions of plastic products are discarded in the environment every year, posing an increasing threat to human health and wildlife. The biodegradation of plastic by fungi serves as a unique and environmentally friendly option to decrease plastic pollution. The purpose of this study is to compare the biodegradation success of four plastic types by the fungal species *Aspergillus flavus*. This review analyzed five publications of the biodegradation capabilities of the fungus *Aspergillus flavus* on percent weight loss data of low-density polyethylene (LDPE), high-density polyethylene (HDPE), polylactic acid (PLA), and a composite of polylactic acid and jute (PLA-Jute). A one-way analysis of variance (ANOVA) test and a Tukey-Kramer post hoc test were conducted to determine whether the differences between the percent weight loss of the various plastic types were statistically significant. The results revealed that PLA-Jute experienced the highest weight loss percentages of 76% after biodegradation *A. flavus*. This review hypothesized that the fungi could degrade the PLA-Jute composite the most effectively because PLA is a biodegradable plastic, and because jute is a type of plant fiber, which can be naturally degraded by most fungi.

Maanini Lakshmanan, Anisha Ramakrisnan & Gabriella LaCour - Exploring A Novel Enterobactin Solution in An Iron-Rich Environment with *Lactobacillus acidophilus* and *Escherichia coli* to Increase Absorption of Ferric Ions to Help Mitigate Iron Deficiency
Governor's School @ Innovation Park

Iron deficiency lessens the body's ability to produce adequate healthy red blood cells that carry oxygen to the body. Enterobactin, an *E. coli* secretion, aids the uptake of ferric ions through binding and transporting Ferrous Sulfate II and III in the body. The probiotic *Lactobacillus acidophilus* (*L. acidophilus*) increases the bioavailability of iron, referring to the absorption and utility of a substance. The hypothesis states that a combination of Ent and *L. acidophilus* will allow for greater iron absorption due to each substance's high ferrous affinity and perceived compatibility. The independent variables consisted of *L. acidophilus*, Ent in an *E. coli* environment, and a combination of Ent with *E. coli* and *L. acidophilus* that were all immersed in an iron solution. The tubes were mixed with o-phenanthroline, which increased the visibility of present iron. Samples were pipetted in a 96-well plate (n = 12) with a Synergy Lx plate reader used to quantify iron absorption. It was concluded that the Ent (2.24 AU), *L. acidophilus*, and the combination of *L. acidophilus* with Ent (2.37 AU) trials all experienced a significant ($p < 0.01$) increase in iron uptake, with the latter demonstrating the greatest absorption in comparison to the controls of the isolated bacterial and iron solutions. However, there was no significant difference between the combination trial and the Ent trials separately, partially supporting the hypothesis. This research has implications for in-vivo systems to explore the effect of this combined therapeutic on treating iron deficiency in the human body.

Audrey Hunter -The Effect of Various Types of Disinfectants, Applied to Bacterial Samples, on the Portion of the Plate Covered by Growth, Over Time
Clover Hill High School

This experiment was conducted to determine the most effective disinfectant when applied to inoculated agar plates which were then incubated. Knowing which disinfectants work best allows people to prevent disease transmission and potentially save lives. Currently, with SARS-CoV-2 and other pathogens posing an active threat, proper sterilization is a serious concern. The disinfectants tested were water (control), Clorox spray, 70% ethanol alcohol, and Purell hand sanitizer. Samples were collected from school desks with cotton swabs, then applied to 120 agar plates. Each disinfectant was applied to 30 plates, which were then placed in an incubator for 93 hours. The plates were sorted into categories based on the amount of visible growth. A Chi Square test was conducted to determine the statistical significance of the data, and it was able to conclude that the data was statistically significant. The median amount of growth was 1-10% for the control group (water), 0% for 70% ethanol, 1-10% for Purell, and 0% for Clorox. No plates treated with Clorox had any visible growth. The Clorox spray was the only disinfectant that contained hypochlorite bleach, which was also found to be effective in other studies. The null hypothesis was rejected, and the data supported the research hypothesis, which was that when applied to inoculated agar plates, Clorox would inhibit the most growth.

Haley Haydon - Which Disinfectant Product is Most Effective in Removing Bacteria?
Chesapeake Bay Governor's School

The COVID-19 pandemic of 2020, brought about an awareness of the best way to disinfect surfaces. The biggest human habitat for bacteria is the skin's surface, most predominately the palms. In order to eliminate the spread of such viruses it is essential to know what works most effectively in removing harmful bacteria. This study tested to see which cleaning product, Clorox wipes, Nature Promise wipes, a wet paper towel, or the control, removes the most bacteria from a surface. This experiment was done in two studies; one focusing on household surfaces and the other on computer keyboards located in a community college. For both studies, agar plates were used to grow the bacteria. In the first study, metal household surfaces such as door, fridge, and toilet handles were sampled. First, a sterile swab was used to collect bacteria before any cleaning product was used. Then the surface was cleaned with a cleaning product and a new sterile swab was used to collect the bacteria left behind. Once all of the samples were taken for each cleaning product the two dishes were placed in an incubator for forty-eight hours. The percent of bacteria removed by each cleaning product was calculated by finding the area that was covered with bacteria in the uncleaned dish and the cleaned dish for each product. These same methods were used in the second study on computer keyboards in a community college. The most common types of bacteria found on the surfaces in both studies included Staphylococcus epidermidis and Micrococcus luteus. In the first study an ANOVA comparing the cleaning effectiveness of each product resulted in a significant P-value of 0.027. A Tukey test then showed the only major difference occurred between Clorox wipes and the control, as well as between the Nature promise wipes and the control. In the second study the ANOVA resulted in a significant P-value of 0.019. A Tukey test then showed that the only major difference occurred between the Clorox wipes and the Control surface. The Nature Promise wipes worked best removing bacteria from household surfaces, while Clorox wipes were most effective in removing bacteria from computer keyboards. These results show

that the surface being cleaned plays a role in which product is best to clean it. By knowing this information homeowners, schools, and businesses can effectively remove bacteria from their surfaces.

Microbiology & Cell Biology C (HS MCB-C)

First Place

Ann M. Hancock Cellular Biology Award

Monona Zhou - Investigating the Dynamics of Heat Shock Factors on its Protective Role against Neurodegeneration
Mills E Godwin High School

Neurodegenerative Disorders (NDs) affect the Central Nervous System (CNS) of the human body. Although research has been conducted to study these diseases, there are no current treatments for completely curing patients. Present-day medicines can only aid in relieving the symptoms and not slow down the progression of these diseases. The detrimental effects and main pathology of Alzheimer's Disease, a type of ND, is attributed to the buildup of Amyloid-beta plaques within neurons, disrupting cellular homeostasis. Heat Shock Factor 1 (HSF1) is a highly important transcription activator and molecular chaperone. Under homeostasis and normal conditions, HSF1 remains in the cytosol and inactive. However, once cellular stress and various proteotoxic conditions arise, HSF1 enters the nucleus and promotes target gene expression. As a result, the investigations of manipulating HSF1 within neural cells and Alzheimer's Disease models aid in further determining future applications and treatments, which will eventually contribute to eliminating NDs. Various mutations of HSF1 were investigated before being expressed into Alzheimer's Disease cell models to analyze the effects of these mutations on cell viability and proliferation. Expressing a deletion mutation was found to have significantly higher rates of cellular expression, through increasing the activity while decreasing the dynamics of HSF1, which was supported through expressing the protein in *Saccharomyces cerevisiae* and neuroblastoma cells. In silicon drug design was also completed for calculating potential small molecules for stabilizing HSF1 at target regions, promoting cell viability through molecular dynamics.

Second Place

Alice Zhang -The Effect of Subculture Times on the Phenotypic Changes of Primary Aortic Smooth Muscle Cells
Mills E Godwin High School

The purpose of this study was to investigate which passages of primary cultures of mouse aortic smooth muscle cells (SMCs) would undergo phenotypic changes from contractile to synthetic during cell subcultures. Vascular smooth muscle cells are located in the media layer of the artery and play a vital role in maintaining normal artery functions. SMCs are normally presented as a contractile phenotype in the body and play an important physiological role in maintaining vascular tone and buffering pulse pressure. However, these cells are also able to undergo phenotypic

changes from a contractile to a synthetic phenotype, causing the cell to lose its contractility and proliferate, leading to diseases such as atherosclerosis and intimal hyperplasia. Primary cultures of mouse SMCs are extensively used as cell models to investigate the pathophysiology of vascular diseases. Therefore, determination of phenotypic changes in primary cultures of mouse SMCs are critical to providing a foundation for vascular research. It was hypothesized that if the primary SMCs underwent eleven cell passages, then there would be a significant phenotypic change from contractile to synthetic. The contractile phenotype was examined by measuring the expression levels of alpha smooth muscle actin (α SMA), a protein involved in the contractility of smooth muscle cells, using Western Blot and confocal microscopy analysis. The summarized results from both analyses showed that α SMA expressions progressively decreased through passages 1 to 11, supporting the research hypothesis. The confocal microscopy assay showed a significant difference in α SMA expressions occurring at passages beyond 5 compared with the control, while the Western blot assay revealed a significant difference at passages beyond 7. The results from this study are supported by past similar experiments that found a significant phenotypic change in rat aortic SMCs after 7 passages. The results from this study will provide a reference to selection of the correct phenotype of SMCs in vascular research. Possible expansions for this study could include the tracking of synthetic phenotype markers as well as contractile phenotype markers to give a more accurate representation of the phenotypic changes in the subcultures of SMCs.

Third Place

Ryan Sloan -The Effect of Common Athletic Materials on the Growth of *Staphylococcus epidermidis*
Central Virginia Governor's School

The purpose of this experiment was to identify materials that are more conducive in allowing *Staphylococcus epidermidis* growth, therefore giving insight as to which materials need to be sanitized much more frequently than others. *S. epidermidis* was exposed to steel, polyester, plastic, and leather samples. The bacteria were transferred onto each material and allowed to grow, then placed in a whirl pack filled with phosphate buffered saline solution. The steel and plastic groups were diluted to 10^{-6} and the leather and polyester groups were diluted to 10^{-5} . These were then grown on tryptic soy agar plates. After this, colonies were counted to determine where the most bacteria grew. After data collection, both a one-factor ANOVA and post-hoc Tukey test were performed. The plastic, polyester, steel, and leather groups had means of 2.1×10^8 , 2.4×10^7 , 1.9×10^8 , and 1.4×10^7 , respectively. The p-value was 8.35×10^{-16} , compared to the alpha of .05. The group that resulted in the most bacterial growth was plastic, followed by steel, and then leather and polyester (which had no statistical significance). This study's research hypothesis, that if *Staphylococcus epidermidis* was exposed to leather, polyester, plastic, and steel, then the bacteria would grow the most on steel, was not supported. Due to an uprising in the prioritization in athletics, this study is applicable to the real world because it gives insight into the nature of bacteria in sports, providing awareness to the risks of bacterial infections.

Honorable Mention

Andy Peacock – Studying Impacts of Glass and Plastic Reusable Water Bottles on Microbial Growth

The main objective of this study was to determine whether or not the material a reusable water bottle is made out of influences the bacterial growth in bottles during use. The hypothesis was that glass containers would resist bacterial growth more than plastic. Four glass cups and four plastic bottles were used for each group; another glass cup served as the control. The nine cups were washed, filled with 180ml of filtered water, and 90ml was drunk from each, while the control was filled, but not drunk out of. Then, the containers were covered in foil and left in a room-temperature cabinet for 24 hours. The next day, 10 μ L (.01ml) water samples were collected from each container, and a cotton swab was used to collect bacteria left on the mouthpieces. The bacteria and water samples were placed in separate Petri dishes and placed in an incubator at 37°C for five days. The colonies in the dishes were then counted and recorded on a table. The colony counts resulted in standard deviations of 27.3, 4.5, and .5. A two-way ANOVA determined no significance, with p-values of .12, .26, and .28 compared to an alpha of .05. Because the two-way ANOVA suggested no difference between bacteria counts in glass and plastic bottles, the research hypothesis was not supported. However, these results may promote the importance of washing bottles regularly as the containers in the experiment were washed between trials.

Honorable Mention

John Smaragdis -The Effect of Different Concentrations of Isopropyl Alcohol in Homemade Hand Sanitizer on Reducing the Growth of Bacteria Commonly Present on Hands
Washington-Liberty High School

Public health officials consider proper hand hygiene to be a first line of defense against the transmission of microbes and infections. The Centers for Disease Control recommends that if alcohol-based hand sanitizer is used, it should have an alcohol concentration of at least 60% in order to be effective. During the early stages of the COVID-19 pandemic, commercial hand sanitizer was often unavailable in the United States and individuals reportedly began to make homemade hand sanitizer using isopropyl alcohol and aloe vera according to instructions widely disseminated on the internet. The purpose of this study was to determine the effectiveness of homemade hand sanitizer made from isopropyl alcohol and aloe vera gel mixed at alcohol concentrations of 45.5%, 60.6%, and 68.25% against *Staphylococcus epidermidis*, a bacterium commonly found on hands. It was hypothesized that the homemade hand sanitizer made with 68.25% isopropyl alcohol would show the greatest inhibition of *Staphylococcus epidermidis* growth because a concentration of 60% to 90% isopropyl alcohol has been shown to be most effective in studies of commercially prepared hand sanitizer. Data collected in this study showed no significant difference in inhibition of bacterial growth among the groups, and the null hypothesis that there would be no difference among the tested hand sanitizers in inhibiting the growth of *Staphylococcus epidermidis* could not be rejected. The data collected suggests

that hand sanitizer made in a home environment may not be as reliably effective in inhibiting bacterial growth as commercially prepared hand sanitizers.

Honorable Mention

Aashka Shah – Studying the Role of Epigenetic Regulators in the Recovery of Triple-Negative Breast Cancer
Maggie L Walker Governor's School

Triple-negative breast cancer (TNBC) is one of the most aggressive forms of breast cancer with an incredibly high relapse and spread rate. Luckily, CRISPR/Cas9 has the potential to prevent the recurrence of TNBC through the use of its high precision in gene editing. Specifically, targeting genes essential for the survival of cancer but not essential for the survival of the patient could prevent recurrence altogether. Further research into the specific biomarkers related to the relapse of TNBC is necessary before utilizing CRISPR to help prevent recurrence. Data from a CRISPR Screening of 450 epigenetic regulators were analyzed to identify epigenetic regulators that prevent the recurrence of TNBC, and golden gate cloning was used to start the first steps of implementing the process of gene knockout. Twenty-seven genes were chosen in total, and two sequences were chosen for each gene. Specifically, Men 1.1 and 1.6, BMI1.6, and TRIM28.1 were found to have the highest potential to prevent recurrence when analyzed by looking at different time points. The major finding of the study was that gene editing with CRISPR has the potential to bring down relapse rates. While issues with experimentation prevented specific rates from being analyzed, a major finding was that golden gate cloning combined with CRISPR technology can be successfully utilized to knock out genes helping prevent relapse in patients. However, further studies are necessary to ensure 100% knockout of the gene, the effect of treatment on patients, and the specific rates of relapse.

Aanandi Parashar – Effect of AGX-51 on Proliferation and Differentiation of Cells with Pulmonary Fibrosis
Hidden Valley High School

Idiopathic Pulmonary fibrosis (IPF) is a chronic, progressive, fibrotic lung disease with high morbidity and mortality with limited treatments currently available. A key feature of IPF is airway remodeling which is driven by fibroblast proliferation and differentiation. Thus, agents targeting the proliferation and differentiation of fibroblasts have a potential role as therapeutic agents for pulmonary fibrosis. AGX-51 is one such agent that has been shown to be an ID1 (inhibitor of DNA binding) antagonist. ID1 proteins have shown to encourage proliferation and differentiation in lung fibroblasts. This study proposes that AGX-51 could impact proliferation and differentiation rates of lung fibroblasts and could therefore be a potential therapeutic agent of this illness. When testing the proliferation of IPF and NHLF (Normal Human Lung Fibroblasts), different concentrations (1, 4, 20, 40, 100 μ M) of AGX-51 were evaluated for their impact on proliferation. When testing the differentiation of IPF and NHLF cells, AGX-51 was used as a treatment on different

genes (αSMA, Col1a1, and Col3a1). The results of proliferation experiment show that concentrations above 20μM are most effective in reducing proliferation rate. The results of the differentiation experiment show that when IPF and NHLF cells were treated with AGX-51, differentiation levels were reduced to the same level as they were in the control trial. In conclusion, the initial hypothesis was correct, the results (using One-way ANOVA) indicate a statistically significant ($P < 0.05$) decrease in both cell types of differentiation rate, as well as a proliferation rate.

Makayla Seamster - Efficacy of Different Topical Antibiotics against Bacteria from Chesapeake Bay water
Chesapeake Bay Governor's School

There are several different strains of bacteria in the *Vibrio* family that occur naturally in coastal waters including: *V. vulnificus*, *V. parahaemolyticus*, *V. cholera*, *V. alginolyticus*. All of these are very dangerous and can cause severe infections and gastrointestinal issues. These bacteria are mainly found along the Atlantic Coast and occur more frequently in warm waters. Meaning the levels of this bacteria in the bay are much higher in summer months. These infections may occur when an open wound is exposed to seawater, or when infected seafood is ingested. Using topical antibiotics when an infection is suspected can stop the infection from progressing. There are many different topical antibiotics on the market that are used for many different infections. For this experiment the efficacy of four different topical antibiotics were tested. These antibiotics were: Curad Wound Gel (Silver), Povidone Iodine, Bacitracin, and Curoxen (Calendula/Oleuropein) all-natural ointment. These treatments were used on water samples from the Urbanna Creek. They were then examined for bacterial growth and a picture was taken of each plate. The before and after pictures were compared to examine the change in percent coverage. Across the tests, three of the treatments resulted in an increase in percent coverage, while the control and the povidone iodine treatment resulted in a decrease in percent coverage. These results show that the topical antibiotics overall did not have a significant effect on stopping the growth of these bacterias after they had already started to grow. While the Curad treatment resulted in a slight reduction of bacterial coverage, it should not be used as a treatment for infection, but a preventative treatment.

Matthew Wang -The Effect of Brewing Time on the Capability of Green Tea to Suppress Growth of the Number of *Fusobacterium nucleatum* Colonies.

The purpose of this experiment was to test a range of brewing times for green tea leaves in order to discover an optimal time that has the best capability of inhibiting the growth of *Fusobacterium nucleatum*. The hypothesis stated that if the green tea leaves were brewed for a longer period of time, the green tea solution would be more effective in decreasing the number of colonies grown. To find the optimal brewing time of the tea leaves, seven different times were tested. Twenty grams of green tea leaves were put into 8 containers each representing a different level of IV. One liter of tap water was boiled in an iron kettle and poured into all containers. The leaves were removed from the 1-minute container

after having brewed for 1 minute. This procedure was repeated with each of the different containers at each of their respective time intervals, and then cooled to room temperature. They were brought to a flow hood and filtered through .22 micrometer filters into separate containers. Five ml of all independent variable levels of the green tea extract were put into separate test tubes, and 500 microliters of *F. nucleatum* solution added into each tube. Two hundred microliters of the solutions were placed on petri dishes prepared with *F. nucleatum* selective agar, then incubated in an anaerobic chamber for 24 hours for the colonies of *F. nucleatum* to grow. The median for the number of colonies grown was recorded, with the highest being the 5 seconds time with 92 colonies. The median for the 10 seconds time was 61 colonies, 25 colonies for the 30 seconds time, 0 colonies for the 1-minute time, 1 colony for the 5-minute time, and 0 colonies for the 10 minutes and 20 minutes times. The null hypothesis of no significant difference was tested using a one-way ANOVA test and was rejected. The results of the experiment support the research hypothesis due to overall the trend of colonies decreasing as brewing time of the tea leaves increased.

Pari Wadnerkar -The Effect of Riboflavin on the Growth of *Staphylococcus epidermis*
Mills E Godwin High School

The purpose of this experiment was to determine the effect of riboflavin on the growth of *Staphylococcus epidermidis*. Riboflavin solutions of 0 mg/mL (control), 0.05 mg/mL, 0.1 mg/mL, 0.5 mg/mL, 1 mg/mL were prepared. 25 filter disks were placed in each solution and were placed in a petri dish streaked with *Staphylococcus epidermidis*. The plates were incubated for 48 hours, and the zones of inhibition were then measured. The results showed an indirect relationship between the concentration of riboflavin and the growth of bacteria. A t-test was performed, and the data was not statistically significant. It is believed that the results were due to the lack of UV light which reportedly allows riboflavin to have an antibacterial effect.

Mary Tolbert - Comparing the Effectiveness of Antibiotics on the Growth of the Bacteria *E. coli*.
Central Virginia Governor's School

The purpose of this research study was to determine which antibiotic out of ampicillin, streptomycin, chloramphenicol, penicillin, and tetracycline would be more effective in inhibiting the growth of *Escherichia coli*. Aseptic technique was used to sterilize the lab space, and utensils used to place antibiotic disk on tryptic soy agar (TSA) plates, smeared with *E.coli* broth. After incubation of the TSA plates, the zones of inhibition, which are the circles that form around the antibiotics, indicating how much of the bacteria was prevented from growing, were measured. The mean of the trials for penicillin was 8.9mm, streptomycin 17.7mm, ampicillin 20.1mm, chloramphenicol 20.3mm, and tetracycline 34.6mm. A one-way ANOVA test was conducted, which resulted in a p-value of 8.53×10^{-11} , compared to an alpha value of 0.05. These results suggested to be statistically significant, therefore a post-hoc Tukey test was performed,

which showed significance in tetracycline compared to all other antibiotics, and in streptomycin and chloramphenicol compared to penicillin. Therefore, the research hypothesis was not supported, which was that chloramphenicol would be the most effective antibiotic when inhibiting the growth of *Escherichia coli*. Testing which antibiotic is the most effective can help determine which antibiotic to use when treating *E. coli* inflicted diseases, such as hemolytic uremic disease (HUS), and kidney infections that are worsened by *E. coli*, amongst other infections. In summation, the antibiotic tetracycline was the most effective antibiotic when tested on *E. coli* and had the largest mean zone of inhibition measurement.

Physics & Astronomy A (HS PHY-A)

First Place

Aaryan Mhaskar – Development of Novel Stimulator to Reduce Electromagnetic Interference During Transcranial Magnetic Stimulation
Mills E Godwin High School

Transcranial Magnetic Stimulation (TMS) is a form of neuromodulation used to treat depression, obsessive-compulsive disorder, migraines, Parkinson's Disease, anxiety, and PTSD. Outside of clinical applications, TMS is used to investigate the pathways of the brain by stimulating specific parts and observing the response and is used on small animals such as mice and rats before it is implemented in humans. Applications of TMS require extreme focality of the stimulation area. However, current TMS devices fail to reach the precision to stimulate specific areas of the brain with a radius <3 mm. As a result, they often stimulate extraneous areas of the brain, interfere with implants in the brain, and are too imprecise for testing on small animals. The goal of the study is to produce a novel design for a TMS stimulator that is precise enough to stimulate areas <3 mm radius for use in small animal heads, research scenarios, and high accuracy. To do so, ferromagnetic cores were designed to improve the focality, and core designs were iterated to increase accuracy. To test the accuracy of the designs, they were imported in ANSYS Maxwell, and the radius of the stimulation area was measured by plotting the electric field in V/m. The final design iteration produced a highly focal stimulation area (1.5 mm radius) using a sharpened C-shape core. This focality has not been reached before and implementing this design will allow wider scope of TMS applications and safer TMS therapy.

Second Place

Nicholas Louvet & Nathan Sprouse -The Effect of Different Eddy Current Brake Designs on the Efficiency of Bike Braking
Roanoke Valley Governor's School

This experiment was done to determine the most effective design of an eddy current brake for a bike. Eddy current brakes have shown to be effective at stopping the motion of a roller coaster or power tools, so their effectiveness on a recreational vehicle such as a bike was sought after to determine their plausibility of replacing or being added to the less efficient and higher maintenance standard friction braking systems. A custom bike wheel with a center of solid aluminum was designed and built, to act as the non-ferromagnetic substance to induce the eddy currents in. Two 12v electromagnets, as well as several permanent neodymium magnets, were tested in several different positions on the

bike wheel. The brakes were tested in a laboratory setting to avoid all possible inconsistencies in testing, with a setup designed for consistency in wheel velocity. The data showed that the permanent neodymium magnets that were arranged opposite each other on the wheel provided the largest slowing acceleration to the bike wheel. Thus, a functioning, toggleable brake was designed with this design in mind to serve as an efficient, safe brake for the bike.

Third Place

Ronan McKinney -The Effect of Positioning Within a Galaxy on Star Formation
Central Virginia Governor's School

The purpose of this study was to determine whether or not a relationship is present between the distance from the center of a galaxy (NGC-253), and the stars that form. The data collected originated from the Very Large Array (VLA) observatory which provided the location of significant star formation sources as well as an image to plot these sources upon. A Python emulator known as SciServer was utilized in order to develop a CSV file which was plotted onto the image of NGC-253. I then calculated the distance between the various sources and the center of the galaxy using the distance formula of $\sqrt{(X_2-X_1)^2 + (Y_2-Y_1)^2}$. A Chi-Square Goodness of Fit test was run in order to determine the significance of my study with an alpha value of .05. The statistical value successfully surpassed the critical value, supporting a potential significance in the data. My research hypothesis which stated star formation concentration would increase towards the center was supported. This study was able to reveal more about the cosmos, and the effect positioning has on celestial bodies.

Honorable Mention

Xavier Ho -The Effect of Various Types of Rosin on Degree of Deviation from Perfect Pitch, Using a Viola
Clover Hill High School

The purpose of this experiment was to determine the type of rosin that would yield the least deviation from the perfect pitch of a note played on the viola. Intonation is one of the most important parts of good instrumentation, and rosin is a key part of playing string instruments. Knowing the best type of rosin for intonation on the viola could greatly enhance the use of the instrument. A bow was adhered to a remote-controlled car, and the car was used to artificially bow the viola. The deviation of the note bowed was tracked by a tuner clipped to the scroll of the viola. Each trial's deviation was recorded in a data table, and there were thirty trials on each level of the independent variable. The five levels of the independent variable were light violin/viola, dark violin/viola, light cello, dark cello, and dark bass rosin. The control, which was the light violin/viola rosin, had a mean deviation of 0.8 ¢. The dark violin/viola rosin had a mean deviation of 0.2 ¢. Light cello rosin produced a mean deviation of 0.5 ¢. Dark cello rosin yielded a mean deviation of 1.3 ¢. Lastly, the dark bass rosin trials yielded a mean deviation of 1.1 ¢. Upon the conclusion of the trial process, an ANOVA test

was conducted to determine the significance of the data. The ANOVA test found that the results of the experiment were significant, as the p value was lower than the level of significance. The experimental hypothesis proposed that dark violin/viola rosin would produce the least deviation, and it was supported. The null hypothesis was rejected.

Honorable Mention

Kelsey Morris -The Effect of Swimsuit Material on Water Resistance
Mills E Godwin High School

The purpose of this experiment was to determine the effects of various swimsuit materials on water resistance. Swimming is a popular sport where water resistance can be influential in a swimmer's race. Swimsuits play a major role in this, and the improvement of swimsuits could enhance the sport for both athletes and spectators. To test the water resistance of the different materials, water was consistently poured on pieces of nylon, polyester, nylon-spandex, and polyester-spandex. The time it took for the water to pass through each material was recorded in seconds. There was no control used in this experiment as all of the tested materials are used often in swimwear, and none are considered the primary material. It was hypothesized that if water is poured on different swimsuit materials, then the nylon-spandex blend will take the most time for water to pass through. A t-test was conducted and revealed that the data was statistically significant for each level of the independent variable. The results displayed that nylon took the most time for water to pass through and, therefore, is the most water resistant. It is believed that the results were due to how the fabrics are knit and the ability of nylon's threads to expand when exposed to water. This research could influence further studies to investigate the different materials' durability in order to determine the most effective swimsuit material.

Maggie Barker -The Effect of Strike Location of a Tennis Ball on a Tennis Racquet on the Distance a Tennis Ball Travels
Clover Hill High School

The purpose of this experiment was to determine which section of a tennis racquet makes a tennis ball travel the greatest distance. Knowing where to make contact with a ball based on the scenario a player is in could promote a player's strategy and skill. The hypothesis of this experiment stated that the balls that made contact with the center of the racquet would travel the farthest distance. The independent variable was where the tennis ball landed on the racquet, while the dependent variable was how far the tennis ball traveled. There were fifty trials conducted, including the ten control trials. The racquet was anchored on a wooden post. Tennis balls were fired at the racquet using a ball machine. Once the ball bounced off of the racquet, the distance was measured between the ball and the racquet. These distances were recorded in a data table. The center section of the racquet averaged a distance of 2.247 m, the

left side of the racquet averaged a distance of 1.389 m, the right side of the racquet averaged a distance of 1.445 m, the bottom of the racquet averaged a distance of 1.525 m, and the top of the racquet averaged a distance of 1.391 m. Based on the averaged data, the center section of the racquet made the tennis balls travel the greatest distance. The research hypothesis was supported by this experiment. An ANOVA test was conducted in order to determine the statistical significance of the data and as a result the null hypothesis was rejected. This experiment could benefit from a more accurate and consistent ball machine.

Susanna Ceglaz -The Effect of Various Brands of Chalk Used in Gymnastics on the Amount of Friction the Chalk Provides
Clover Hill High School

The purpose of this experiment was to determine the effect of various brands of chalk used in gymnastics on the amount of friction the chalk provides. The purpose of this experiment was to determine which gymnastics chalk brands provided the most friction to prevent injuries. The hypothesis was that if the control, Rage Fitness chalk, Cramer chalk, and Nexo Fitness chalk were all tested the same way, then the Rage Fitness chalk would provide the most friction. For the experiment, twenty cups and two bags were marked for each chalk brand. The chalk was placed in the bags labeled with its brand name and crushed. Twenty grams of powdered chalk were added to each cup labeled for that brand. Next, a 170-centimeter ramp was made from wood. The ramp had a starting and stopping place for the remote-control car. Then, a hook attachment was screwed onto a spring scale and was connected to the car using a piece of yarn. The scale was set to Newtons and the car was placed at the start. Once set, the car proceeded to drive up the ramp, pulling the spring scale with it. Everything was cleaned with a wet wipe and the procedure was repeated twenty times for the control and for each chalk brand. The highest mean was the Nexo Fitness chalk, which was 2.090 N, second and third were the Rage Fitness chalk and Cramer chalk brands with 1.659 N and 1.575 N respectively. Last was the control with only 1.560 N. Due to the One-Way ANOVA test that was conducted, the null hypothesis was rejected. Since the research hypothesis was not supported by the data, it was rejected as well.

Benjamin Foster -The Effect of Various Types of Tennis Court Surfaces on the Height of a Tennis Ball Bounce
Clover Hill High School

The purpose of this experiment was to determine the effect of the surface on the height that a tennis ball rebounds off to. Knowing which surface produces the highest bounce height allows tennis players to better prepare for playing on different surfaces. To measure the height, the balls were dropped in front of a poster from a pipe contraption that dropped the balls at an angle. The drop of the balls was recorded on an iPhone and reviewed to determine the height. The four levels of the independent variable were the control, an indoor artificial clay tennis court, an outdoor artificial

clay tennis court, and a golf course putting green. A golf course putting green was used in place of a grass tennis court due to the lack of available grass tennis courts. The heights were recorded in a data table, and this process was repeated until each level had 60 complete trials. The control surface (a hard tennis court) produced a mean height of 69.34 centimeters. The artificial clay tennis court led to an average height of 69.96 cm. The indoor artificial clay tennis court generated an average height of 67.45 cm. The golf course putting green had a bounce of 37.01 cm on average. After the data was collected, an ANOVA test was conducted to test if the data was statistically significant. The results of the conducted ANOVA test stated that the results were significant, leading to the rejection of the null hypothesis. The experimental hypothesis of the experiment was that the indoor artificial clay tennis court would produce the highest tennis ball bounce, followed by the outdoor artificial clay tennis court, and the golf course green would produce the lowest bounce. This was not supported.

Henry Frankenberry -The Effect of Brand of Tennis Balls on Height of Ball Bounce
Clover Hill High School

The purpose of this experiment was to determine the effect of the brand of tennis ball on height of ball bounce. The different tennis ball brands have varied bounce heights and the goal was to see which ball had the highest bounce. To measure the height of the tennis balls' bounce, the balls were dropped from the same height at the top of the meter stick, and the drop was recorded with a slow-motion camera. The footage was then reviewed to see how high the ball bounced. The independent variable was the brand of tennis ball, and the five levels of the independent variable were Wilson Championship, Penn, Dunlop, Wilson US Open, and Franklin. The bounce heights were recorded, and this was repeated 30 times for each level of the independent variable. All trials were conducted on the same day in order for the environmental conditions to be as constant as possible. The mean bounce height of the Franklin tennis balls was 45.212 centimeters, 59.140 cm for Dunlop, 58.251 cm for Penn, 61.469 cm for Wilson US Open, and 60.537 cm for Wilson Championship. A one-way ANOVA test was conducted. The calculated F value was 226.87916 and the null hypothesis was rejected. The research hypothesis was: The Wilson US Open tennis balls would bounce higher than the other brands of tennis balls. The hypothesis was supported because the Wilson US Open balls bounced the highest at 61.469 cm.

Ava Grace Kennedy -The Effect of the Angle of Attack on a Prototype Airfoil
Central Virginia Governor's School

The purpose of this research project was to find the most effective and efficient wing angle on a prototype wing. In this experiment, four Vernier Force and Acceleration monitors attached to each side of the wing. From there, 10 trials were tested for each angle interval, 0 to 30 degrees above the horizontal. My results showed that my data was significant

as it showed that 0 degrees had the greatest lift to drag ratio, making it the most efficient for flight. The statistical test used was a Single Factor ANOVA with replication. The compared alpha value was 0.05 and my p value sample was 1.35×10^{-5} and my p value for my columns was 2.23×10^{-9} . The research hypothesis was supported as it shows that any angle closer to the horizontal has a decreased drag coefficient, making the lift coefficient greater.

Luri Lee -The Effect of Angles of Lighting, hitting a Painting, on the Difference in Color (px), Analyzed Using ImageJ Software
Clover Hill High School

Light and color had always interacted with each other in fascinating ways. Although these concepts could be attributed to multiple facets of science and technology, their contribution to art had remained one of the most recognizable uses. In this experiment, the question of how light affected color, specifically in a gallery setting (i.e., a painting), was addressed. The hypothesis stated that the less directly the angle of light shone on the painting (the further the angle of light was from the control), the more the color in the painting would differ from its original state. Five 20 cm x 25 cm canvases were labeled, then painted with blue acrylic paint. For each level of the independent variable, one painting was laid flat on a desk. A lamp was used as the light source, with the angle of the lamphead having been adjusted vertically using a bevel box. Photos of the painting under each angle of lighting were taken, and then transferred to ImageJ as jpg files. Finally, the mean RGB values of the photos were collected in ImageJ. The closer the angles of lighting were to the control of 90 degrees, the more correspondent the values became with it, i.e., less direct lighting produced the most difference in color. Subsequently, the null hypothesis was rejected by the p value from the ANOVA test.

Delaney Lewis -The Effect of Infill Percentages on the Structural Integrity to Mass of Material Ratio
Central Virginia Governor's School

The purpose of this study was to determine whether or not infill percentage had any effect on the strength to mass ratio of a 3D printed object. The hypothesis was that a 50% infill would result in the most optimal ratio to minimize the cost of material while maintaining strength. Four groups of ten rods made using (PLA) plastic with increasing infill percentages were tested by applying force in newtons until they broke in half. This value was recorded, and a one-way ANOVA test determined significance with a p-value of 2.61×10^{-4} and an alpha level of .05. A post-hoc Tukey test then determined that a significant difference was found between all groups. After statistical significance was ensured, the average of the force endured by the ten rods for each group divided by the mass of a rod with corresponding infill percentage was recorded to find the optimal force to mass ratio. The infill percentage that resulted in the greatest strength relative to mass of material used occurred at an infill of 10%. The weight supported per gram of material at

10% infill was 16.53 N/g. The results of this research can help engineers design materials and structures to maximize strength while reducing material cost.

Andrew Miller -The Effect of a 3d Print's Extrusion Temperature on its Compression Strength
Yorktown High School

The purpose of this project was to determine the optimal extrusion temperature for 3d printing with polylactide (PLA) plastics with specific additives. PLA's advantageous properties and high availability have made it the material of choice for prototyping. However, a dilemma emerges when using an additive process such as 3d printing; the material ceases to adhere to itself. As a result, crumbling. If consumers had information on how temperature affected compression strength, they could stretch the limits of their designs and save resources. Before experimentation, further exploration of PLA's properties was conducted using the specific heat equation, which led to the following hypothesis: if the extrusion temperature is within 101.667-104.444° C (215-220° F), then the 3d print will adhere while not losing structure. The previous temperature ranges were chosen via the known melting point of PLA, the known effects of additives, and lost energy. Procedures included slicing 50x20x20 mm blocks in Cura (a slicing software), with each set of three blocks printed at their respective temperatures. Samples were then tested using compression force from turning a vice, fifteen degrees at a time, until there was an observable deformation. Observations from the data made it apparent that the higher the extrusion temperature, the higher the compression force the block withstood. However, this strayed from the previously constructed hypothesis, which overcompensated the effect of additives on PLA's adhesion and melting temperature. Previous research published in *RSC Advances* indicated compression strength would eventually plateau. This discrepancy is cause for further research.

Sebastion Monroy – The Effect of Flap Deflection Angle on an Airplane's Takeoff Time and Speed
Washington-Liberty

The purpose of this experiment was to find the optimal angle of flaps on an airplane to allow it to takeoff in the shortest amount of time possible. It was hypothesized that if the flaps on an airplane are set to an angle of around 20 degrees, then the airplane would use the least distance to takeoff because this angle increases the camber of the wing enough to provide the maximum lift coefficient without producing excessive drag force that comes from higher flap deflection. The null hypothesis was that no matter if the flaps are set at any degree, there will be no difference in the takeoff time. This experiment was carried out and conducted using Microsoft Flight Simulator 2020. The independent variables in this experiment consisted of the different planes that were going to be tested and the angles of flap deflection that were going to be tested. In total, 9 planes were tested: The Airbus A320neo; Airbus A310-300; Canadair's CRJ models 550, 700, 900, and 1000; Boeing 787-10; and the well-known 747-8i. The last plane was the Aerospatiale/BAC Concorde

which was only tested at 0 degrees (control) because it serves as an example of a plane with no high lift devices (flaps or slats). The angles tested varied per plane due to differences in the flap settings between the models and manufacturers, so not all of the planes were tested at all angles. The dependent variable was the amount of time in seconds it took for the plane to achieve a positive climb rate as well as the speed in knots of when the plane achieved that rate. For all of the planes, the control was 0 degrees. The A320neo was tested at 10, 15, 20, and 35 degrees. The A310-300 was tested at 15, 20, and 40 degrees. The Bombardier CRJs (CRJ550, CRJ700, CRJ900, and CRJ1000) were all tested at 1, 8, 20, 30, and 45 degrees. The Boeing 787-10 was tested at 1, 10, 15, 20, and 30 degrees. The Boeing 747-8i was tested at 10, 20, and 30 degrees. After the experiment was conducted, most of the planes showed a large decrease in takeoff time from the control to the first flap setting. Takeoff times also decreased as the flap angle increased, but at a lower rate compared to the initial angles. The takeoff speed also decreased due to the increased lift. The hypothesis was not supported by the results, but the null hypothesis cannot be accepted a must be rejected, because there was a difference in the takeoff time based on the flap deflection.

Physics & Astronomy B (HS PHY-B)

First Place

Colby Schietinger -The Relationship Between Radio Sources and HCN Regarding Star Formation
Central Virginia Governor's School

This study aimed to determine whether radio sources within a galaxy correlate with its HCN (hydrogen cyanide) content. The experiment was conducted by using Astro Python to analyze data from a high-definition image of galaxy NGC 253 that contained information about its location and contents. The galaxy was separated into 95 hexagonal regions, then the number of radio sources per region were quantified, and a regional HCN value was assigned using python image analysis. The number of radio sources per region were then compared to their corresponding HCN value. Using a linear regression test, a p-value of $8.76E-12$ was calculated and when compared to the alpha value of .05, the results indicated a significant correlation. The results supported the hypothesis of a correlation between the radio sources found within a region of a galaxy and its corresponding concentration of HCN. In conclusion, regions with a larger quantity of radio sources are likely to contain a higher density of HCN than other regions in a galaxy, leading to increased star formation rate.

Second Place

Eva Siminiceanu, Olivia D'Ambrosia, & Maria Van Deusen - How Tennis Ball Spin Affects Horizontal Distances Traveled Before and After Bouncing
Collegiate School

Forward and backward spins, or topspin and backspin, as referred to in tennis, are commonly used in the sport to manipulate the horizontal distance that the ball travels after being struck with the racquet. Using spin to change the angular velocity of a ball affects a force called Magnus force, which is the main reason why the horizontal distance traveled changes as the spin changes. A better understanding of Magnus force and the other forces that act on a tennis ball can inform decisions made regarding spin while playing tennis. The objective of this experiment was to analyze how the strength and type of the spin affect how far the ball travels after being launched. The ultimate goal is to determine whether forward and backward spin affect the horizontal distance the ball travels. We considered the horizontal distance between when the ball is struck to its first bounce, and the distance between the ball's first bounce to its second bounce. These distances were considered because according to the rules of tennis, once the ball bounces

twice it is deemed out of play, so those distances are the most relevant to the sport. In this experiment, a ball machine was used to keep the launch angle and velocity of the ball constant, so that only the direction and strength of the spin of the ball would change. The distance the ball traveled before its first and second bounce was then measured. Although there are some confounding variables due to imprecise measuring, wind, hand-held timing, and unevenness of the court that the data was being collected on, the data collected aligns with previous physics research. Analysis of the data shows that topspin causes the ball to travel a shorter distance in the air and a longer distance after its bounce compared to backspin, which causes the ball to travel a longer distance in the air and a shorter distance after the bounce. Future studies could add to this research by studying other variables that are affected by the spin, such as the vertical distance traveled and the translational and angular velocities of the ball.

Third Place

Stephen Tibbs -The Relationship Between Fluid Density, Sound Frequency, and Amplitude
Central Virginia Governor's School

The purpose of this study was to explore the relationship between fluid density, sound wave frequency, and change in amplitude. This study was conducted at a local high school from November 2022 to January 2023. A sound sensor and speaker were placed at opposite ends and the same side of a tub filled with water at room temperature to collect data. Trial sets were run with 1600hz, 1400hz, and 1200hz sound waves in saltwater and tap water in the tub. The air trials were set up on a table with the same distance between the speaker and sensor. The average change in amplitude of the saltwater groups were -.059m for 1600hz, -.067m for 1400hz, and -.012m for 1200hz. The average change in amplitude of the tap water groups were -.791m for 1600hz, -2.592m for 1400hz, and -.794m for 1200hz. The averages of the air groups were -2.028m for 1600hz, -3.018m for 1400hz, and -4.363m for 1200hz. The two-way ANOVA produced a p-value of 9.97×10^{-45} (alpha .05), therefore showing significance between some groups. The post-hoc Tukey test showed significance between all groups except between tap water 1200hz: tap water 1600hz, saltwater 1200hz; tap water 1600hz: saltwater 1200hz; saltwater 1400hz: saltwater 1600hz. It did not support the research hypothesis that 1200hz sound waves would keep their amplitude the best. In conclusion, the data indicated that 1600hz and 1400hz sound waves in saltwater are conserved the best.

Honorable Mention

Jingtong Zhou -The Effect of Various 3D Printed Shoe Tread Patterns on the Amount of Force Required to Move the Patterns across both Dry and Wet Surfaces
Clover Hill High School

The purpose of this experiment was to determine the shoe tread pattern that generated the most traction from a

standstill. Knowing what patterns produce the most traction can help consumers and athletes know which shoe tread pattern will suit their needs best. To measure the traction, 3D shoe patterns were dragged across both a dry and wet surface with a spring scale. The amount of force needed to pull the patterns was recorded. The different 3D patterns included a control flat surface, a herringbone pattern, a grid pattern, a ribbed pattern, a waffle pattern, and a spotted pattern. On the dry surface, the highest mean was the ribbed pattern with an average of 0.717 N followed by the grid pattern with a mean of 0.642 N. On the wet surface, the ribbed pattern still had the highest mean of 0.318 N followed by the waffle pattern with a mean of 0.312 N. The null hypothesis of no significant difference was tested using a two-way ANOVA test, and the null hypothesis was rejected. The experimental hypothesis was that the shoe pattern with the herringbone pattern would need the most force to move and the force needed to move the patterns across the wet surface would be less than the force needed to move the patterns across the dry surface. The data did not support the experimental hypothesis and the experimental hypothesis was rejected. The results indicate that having a wet surface significantly reduces friction between the shoe and the floor and therefore requires less force to move. The data support that a ribbed shoe pattern is the best for traction as it needed the most amount of force to move on both wet and dry surfaces.

Hannah Neely -The Effect of Depth of a Lacrosse Stick Pocket on the Speed a Lacrosse Ball Travels
Clover Hill High School

Lacrosse from the women's perspective has generally differed from the men's game, and in turn, has created severe obstacles in growth as well as safety. The athlete's ability to effectively perform is hindered by the stick's composition. For example, shallow pockets are required due to lacrosse regulations that limit contact among players, so a safer environment can be created. However, the design has generated more issues and injuries rather than its original intent. To replicate the form of an athlete, a catapult was constructed to hold a women's lacrosse stick using wood, screws, and eye hooks. A pull-back system was created, which allowed the ball to travel forwards. The speed (kph) was recorded with the use of a radar gun. The independent variable of the experiment was different pocket depths, the different levels being 2.5, 3.8, 4.5, 5.2, and 6.5 centimeters. The experimental hypothesis of the experiment was that if different pocket depths such as 2.5, 3.8, 4.5, 5.2, and 6.5 cm were all tested, the deeper pocket depths would result in a faster mean speed. This hypothesis was supported. After 40 trials were done, data was collected in a table and graph. A one-way ANOVA test was done, showing that the results were significant. The null hypothesis was rejected.

Sarah Ramsey – Determining the Most Effective Shin Guard Brands Against Impact
Central Virginia Governor's School

The purpose of this study was to determine whether or not the brand of shin guard had an effect on providing adequate

protection to soccer players through shock absorbance when tested against a constant impact force. This study was conducted at a local high school in a lab setting during December of 2022. Five different brands of soccer shin guards were tested: Nike, Adidas, Puma, Wilson, and Franklin. Each brand was tested with the same impact force of 1 kg (1000 grams) and released from the same height and distance away for 12 trials which means a grand total of 60 data points. This data was analyzed using a single factor ANOVA which determined statistically significant differences. Because of this, a post-hoc Tukey test was used and displayed the largest difference between Adidas and Wilson. The ANOVA, with an alpha level set at 0.05, revealed a p-value which was 0.03. This statistically significant value supported the research hypothesis, which was that if five different brands of adult, size large, sleeve-inserted shin guards were tested by hitting them in a consistent spot with the same amount of force, then the more expensive ones will experience the lowest maximum acceleration and therefore, lowest maximum force. In summary, the brand of shin guard significantly affected the amount of protection offered to soccer players in terms of shock absorbance when tested against an impact force.

Kathleen Rawls -The Effect of Using Various Types of Rock-Climbing Chalk, Applied to Simulated Skin, on the Static Coefficient of Friction Between the Chalked Skin and a Rock
Clover Hill High School

The purpose of the experiment was to determine which of three commonly used forms of rock-climbing chalk (loose, liquid, and cream) was the most effective in increasing the friction between the skin and rock. Loose climbing chalk is often used in place of liquid and cream chinks, but loose chalk has a greater potential to cause harm to the environment and body, making the other two better alternatives for regular climbers. Finding a more effective alternative to loose climbing chalk could, consequently, encourage climbers to gravitate towards a less harmful alternative. The hypothesis was that if loose climbing chalk was applied to simulated skin, the static coefficient of friction would be higher than that of liquid or cream chinks. Each brand of chalk was distributed onto pieces of simulated skin and then placed on a stone plate with a weight on top. A spring scale was attached between the chalked skin and a programmable car. While connected to the chalked skin, the programmable car ran a program instructing it to move forward at a constant speed, dragging the weighted skin along the stone. For the control group, pieces of simulated skin underwent the same process without any chalk. The force required to initiate the movement of the skin (N) was measured and recorded using a spring scale. Both brands of loose chalk resulted in a lower static coefficient of friction than even the unchalked skin. One brand of cream chalk produced the highest coefficient of friction and was found to be the most effective, but the other brand of cream chalk produced the lowest coefficient of friction. The null and experimental hypotheses were both rejected, contradicting both past experiments and the belief that chalk improves one's ability to retain a hold on the rock by increasing the coefficient of friction between them. Further testing is required to determine the impact of other conditions such as moisture on the effectiveness of the various chinks.

Allegra Vena -The effect of Altitude on Muon Flux
Wakefield High School

Muon events are ones that can cause damage on impact. They can cause “bit flips” or data conversion in electronic device memory, mechanical errors and even mutations in DNA. When muons travel from the ozone layer to the surface of the Earth, they have only a short time before they decay into photons. As muons, their mass and energy can cause the damage mentioned above. It is hypothesized that more muons will be detected at higher elevations than at lower elevations. This would show higher risk to computer data and humans at higher elevations. Muon flux data for three approximately 20-hour periods was collected from seven sites across the world, which was accessed from the internet site, Quarknet.org. The muon events (flux) were then averaged over those three periods and compared to the average elevation at each site. A graphical comparison of elevation vs. flux was then graphed, and a linear regression performed. The correlation coefficient (r^2) was calculated to be 0.933—a value which implies an extremely significant correlation result. This implies that the null hypothesis can be rejected, and that muon flux is indeed related to elevation on Earth. It is predicted that computer data systems will work ever harder to protect bits from flipping and crashing systems. The continued use of expensive ECC (error correction code) will drive down the cost, so that modern technology can use more compact storage and still be protected from single event upsets.

Camellia Sharma -The Effect of Dispensing Mechanism on Drop Precision
Mills E Godwin High School

Glaucoma is a group of diseases that lead to structural optic neuropathy and functional deficiency in vision. Worldwide, 80 million people have glaucoma with a blindness rate of 12%. There is no cure for glaucoma, but it can be managed effectively with disciplined use of daily eyedrops. However, eye drops are difficult to administer correctly due to shaky hands, incorrect amount of force applied, and applications of medicine on the eyelids or eyelash. Therefore, a more precise way of administering this medicine topically could help many people treat eye diseases. This study compared the difference between two experimental groups of piezoelectrical crystals and compressed air to see how precise they were compared to the control group of administering by hand. Prototypes for each of the three experimental groups were created using a combination of 3-D printing, eye dropper bottles, and the appropriate experimental material. These prototypes were tested by creating 25 drops of four different volumes (25 μL , 40 μL , 55 μL , and 70 μL). The percent error was calculated for each of these tests. The mean and standard deviation were calculated as the measure of central tendency and spread, respectively. A t-test was performed to determine the significance at the 0.05 level. Both tests of the experimental group versus the control were statistically significant rejecting the null hypothesis that the control and experimental group had an equal mean in favor of the alternative hypothesis. Future work for this study includes a cost-benefit analysis of materials and testing more mechanisms.

Joshua Webb -The Effect of Cleat Upper Material on Ball Velocity
Central Virginia Governor's School

The purpose of this study was to determine how the material of different soccer cleat uppers affected the velocity of a soccer ball when shot. Five male, high school aged, right-footed soccer players performed five instep shots from the penalty kick spot each day over two days for four cleat upper material types: synthetic (Adidas Nemeziz 17+ 360 Agility FG), synthetic leather (Adidas F5 TRX FG), kangaroo leather (Nike Tiempo Legend 8 Elite Tech Craft FG), and only socks (Copa Zone IV socks). The trials were recorded and then analyzed in Vernier Video Analysis to determine the maximum velocities of each kick in meters per second. All trials were conducted at a local high school's soccer field on days with similar weather conditions. A single factor ANOVA was run to determine if there was a significant difference in ball velocity caused by changing the cleat upper material. The p-value produced was .646 and, when compared to an alpha of .05, the null hypothesis was retained. The research hypothesis, if different materials of cleat uppers, synthetic, synthetic leather, kangaroo leather, and only socks, are used to perform several shots, then the velocity of the ball will be the greatest when using kangaroo leather, was not supported. In conclusion, the results suggested that there was no difference in ball velocity caused by a change in cleat upper material.

Christian Singleton -The Effect of Drumstick Material on Pitch and Length of a Sustained Note
Clover Hill High School

Every single sound has a specific pitch and length that makes it identifiable. The specifics of each sound are pertinent information to drummers when tuning their drums. The question of whether or not different types of drumstick materials produce different pitch or durations has been posed by many drummers but has never been truly defined. This study addressed two hypotheses, the first being that changing the material of a drumstick from hickory would lead to an increase in note pitch, the second being that the same change would lead to an increase in note duration. A kick drum beater was fashioned into a tool to strike a tom and data was collected using a tuner and a camera. It was found that changing the material had minimal effect on pitch, but the addition of a nylon tip shortened the length of the note. The results suggest that for the first pitch-based hypothesis, the null hypothesis was not rejected and for the second length-based hypothesis, the null hypothesis was rejected. The data did not support either of the research hypotheses.

Anish Viswanath - Replicating Mechanical Turbulence with Different Factors
Mills E Godwin High School

This study was completed to determine which of three mechanical turbulence factors produce the highest elevation of turbulent flow. The hypothesis stated that the elevation of the turbulence would be highest when the model building is

used. Observing the flow of air around different mechanical turbulence factors can help individuals such as pilots and flight agencies to create routes to encounter the least turbulence. A fan was placed at a distance from the model turbulence factor. A string is held above the model while the fan is running causing the string to come into contact with the turbulent waves. It is then raised until the air flow is undisturbed, and the height is noted. The results showed that the model building produced the most turbulence, the mountain the second most, and the ocean the third most. A t-test was performed on the data and showed that all of the data was significant when compared to one another. The most likely reason as to why the building model produced the most turbulence is due to the sharp angle most buildings have when wind hits against them. Other studies have been done in the past and have shown that turbulence levels in city areas such as Manhattan and Tokyo are high. Future studies can test other types of turbulence such as thermal turbulence or frontal turbulence.

Claire Wiley - Effect of Temperature on Tennis Ball Bounce
Wakefield High School

This experiment measured the effect of different temperatures on the bounce height of tennis balls. This was done to determine the consistency of tennis ball bounce, and what temperature they should ultimately be kept at for tournament officials to note and keep match play fair. The experiment was completed by keeping 3 tennis balls at 3 different temperatures (hot, room temperature, and cold), and measuring how high each ball bounced in inches. The results showed that the tennis balls kept in a cold environment bounced significantly lower than those of hot and room temperature. This suggests that the optimal temperature to keep tournament-ready tennis balls is 68°F.

Psychology A (HS PSY-A)

First Place

Samantha Callahan - Relationships Between Gender and Human Perception
Central Virginia. Governor's School

The purpose of this study was to examine the relationships between physical gender expression and perceptions of academic intelligence and practical capability. Data was collected through a survey sent to participants through email that presented them with images found free online that they were to rank in each of the categories mentioned above. A series of correlations were conducted in order to examine relationships between the variables, none of which yielded r-statistic values more extreme than the r-critical value .361 obtained from the table of r-critical values for degrees of freedom 28. The data did not support the research hypothesis which stated that stereotypically feminine individuals would be perceived as more academically intelligent but less practically capable than their stereotypically masculine counterparts. Because the data was statistically insignificant, no conclusions can be made that physical gender expression has a relationship with academic intelligence or practical capability perceptions.

Second Place

Layla Gaines -The Effect Color has on Memory.
Chesapeake Bay Governor's School

Memory is the "mental process of encoding, retaining, and retrieving" information that is encountered. Memory can be improved in many different ways. These ways include chunking, elaborative rehearsal, mnemonic devices, and spaced repetitions. It has also been suggested that memory and recollection may be improved with different colored fonts. This study compared the amount of words recalled between tests that were in black font and tests that were in red font. There were 44 students that received parental consent and completed the tests. The first test consisted of a list of 20 words that were all in red font. The second test consisted of 20 words all in black font. The third test consisted of 10 words in black font and 10 words in red font. It was hypothesized that word recall would be the greatest with red font, with 50/50 font in the middle, and the least with black font. The control in this study were the tests with all black font. The participants had three minutes to look at the test to try and remember as many words as possible. After their time was up, they had two more minutes to write down any words that they recalled. Students recalled more words with the tests that had 100% red font. An ANOVA statistical test comparing word recall to font color resulted in a p-value of 0.154484 that was trending towards significance. This data rejected the null hypothesis. This study is important because it allows researchers to understand the human brain just a little bit more. It also helps students learn how they

can study to improve their memory and condition their brain properly. The big picture of this study is how to help people who struggle to learn from the standard black font that was used since the beginning of their learning experience.

Third Place

Laken Barnette - Evaluating Comfort Levels in Teenage Patients When Talking to a Physician About Sensitive Topics
Southwest Virginia Governor's School

The study of adolescent patients and their perceived comfort levels will further address comfort concerns to improve the quality of care received. While certain factors were known to cause changes in comfort, such as the gender of the physician and the additional presence of a family member or medical professional, few studies focused solely on patients of adolescent age. To determine if these factors and the gender of the adolescent patients influence comfort, a survey, composed of 5 scenarios in which the participant was asked to rate their comfort talking to a physician about a sensitive topic, was given to a sample of 52 participants 15 to 18 years of age. Furthermore, the null hypothesis tested was that the gender and comfort of adolescent patients when talking to a physician about a sensitive topic, depending on an outside factor, are independent. Additionally, the alternate hypothesis was that gender and comfort among adolescent patients when talking to a physician about a sensitive topic, depending on an outside factor, are dependent. To test the hypotheses, a Chi-Squared Test of Independence and corresponding p-values were calculated. The p-values for the first, second, third, fourth, and fifth scenarios of the survey were 0.4603, 0.1446, 0.6386, 0.0292, and 0.0054, respectively, all of which used a corresponding alpha value of 0.05. Therefore, the results of the first three scenarios of the survey were not significant, so the null hypothesis was rejected for those scenarios. However, the results of the last two scenarios were significant, so the null hypothesis was not rejected. The conclusion was that the gender of the patient and the level of comfort talking to a physician, with the others present, were independent, in addition to the gender of the patient, and the level of comfort talking to a physician of a particular gender was dependent. The application of the results may include asking, before a consultation, if there is a preference for the gender of the physician they will see, or if anything could be done to increase patient comfort.

Honorable Mention

Caoilainn Christensen - Comparative Content and Engagement Analysis of Credentialed and Non-Credentialed Nutrition Professionals on Instagram
Blacksburg High School

With the relatively unregulated nature of social media, any accounts following the platform's guidelines can provide medical information. Nutrition information, specifically, is shared by both credentialed and non-credentialed nutrition professionals. This information warrants the question: what are the major content and engagement differences on

Instagram between registered dietitians and nutritionists and nutrition professionals without a registered nutrition license? Although there has been research comparing these two groups, most of the research has focused on Twitter and blog posts (Titova et al., 2022). Content from different platforms serve different purposes and come in different formats (Pelletier et al., 2020). To study these groups on Instagram, two populations of ten accounts each were selected to be compared. The five most recent posts were used to find the themes and engagement. The captions, like counts, and comment counts were collected. Through the content analysis software NVivo, the captions of each group were coded into the most common content themes. From the credentialed population, the themes fell largely under the categories of emotions and mind-body connection. From the non-credentialed populations, the themes fell largely under the category of science-based strategies. Additionally, the credentialed population had higher mean like and comment counts compared to the non-credentialed population's mean like and comment counts. It was concluded that the credentialed population's content revolved more around emotions and had higher engagement while the non-credentialed population's content was more focused on science-based claims.

Jasmine Faulkner - How Does Performing Impossible Tasks Affect High Achieving High School Students' Confidence in Performing Simpler Tasks?

Southwest Virginia Governor's School

Confidence levels have become a primary factor of success in schools worldwide. Many aspects of life contribute to a student's confidence. High achieving high school students are typically considered to have higher confidence levels attributing to their higher success rates. In this project their true confidence was tested by being assigned tasks with mixed levels of difficulties. This study used a series of crossword puzzles, one of which being deemed impossible, each preceded by a one question survey prompting the subject to rate on a Likert scale their confidence in being able to complete the next task. Many studies unlike this one have simply asked the student how confident they are in performing certain assignments or everyday tasks. This project, however, strived to show how their confidence related to real success, and in sequence with tasks of varying difficulty. This study concluded with insignificant results following two types of analysis tests. This research study could have been used to potentially inform and encourage students as well as teachers in how to ensure higher success rates across the board. Clearer results could have been generated if the puzzles came from a research-based source, instead of created by the student researcher.

Allison Clark - Scientific Reading Comprehension and Confidence of Scores on Tests

Southwest Virginia Governor's School

Scientific reading comprehension is a much-needed skill for all students and scientists around the globe; however, the national standard for upcoming researchers has been decreasing. A main point of research should be accessibility for

everyone, but scientific jargon makes understanding hard for younger scientists. The goal of this study was to understand how scientific jargon affects students when they are administered tests. Two tests were made with the same questions but different wording for each test, one with scientific jargon, and the other with more basic vocabulary utilized. Each test contained five questions, and afterwards, the participants were asked to rank how they felt they did on the questions using a Likert scale. Once the data were obtained, a chi squared test was performed. The chi squared test compared the participants' Likert responses from each different test. The results of the chi squared test indicated that only two questions out of five questions from the tests were significantly different. There are multiple reasons why only two out of five questions produced significant results. Finding wording was a major complication within creating the test. The test was made so that everyone could confidently take it; however, question five was the question that required the most general knowledge. Coincidentally, question five produced the most significant results. Question two was a basic question, and produced a significant p-value, so wording does make somewhat of a difference. Another major complication was sample size. Only 25 participants took part in the survey. This was not enough to ensure fair, honest results. Ideally, there should be 60 participants with 30 in each group. Overall, if the project was done again, more participants should produce more accurate results. More participants, more time, and more resources are needed to see if jargon truly affects comprehension.

Abi Brigman - Childhood Emotional Abuse as a Predictor for Low Self-Esteem as an Adult
Central Virginia Governor's School

The purpose of this study was to see if there was a correlational relationship between emotional abuse and low self-esteem. A sample of data, originally collected by researcher Anna Freier, was divided into two groups, a group that identified as having experienced emotional abuse and a group that had not. Participants' answers indicating abuse (or lack of) were compared to their answers relating to their self-esteem levels. Using a statistical correlation, the data showed a significant relationship between the variables. The group that did not indicate emotional abuse in their survey reported an R-value of .100515. Using an alpha value of .05 compared to the critical value of .043811 the data showed significance. Additionally, the group that responded to the survey indicating they had been emotionally abused during their childhood reported an R-value of .265934. Using the same alpha value as the unabused group, the data was compared to the critical value of .250035 resulting in a statistically significant correlation. These results supported the research hypothesis that if a person self-identified as experiencing emotional abuse in their childhood, then they were more likely to suffer from low self-esteem as an adult. The statistically significant relationship between emotional abuse and low self-esteem should be studied further to identify abuse early on and administer treatment accordingly.

Psychology B (HS PSY-B)

First Place

Isabelle Mistretta - The Effect of Speaker Accent on Listener Perceptions of Intelligence and Solidarity
Central Virginia Governor's School

The purpose of this research was to determine what effect speaker accent has on listener perceptions of speaker intelligence and solidarity with the listener. In December 2022, listeners were presented with audio recordings of four American English accents and asked to rate each speaker in terms of intelligence and solidarity with the listener on a five-point Likert scale (1 being negative, 5 being positive). The mean values collected for intelligence perceptions by accent were 2.80 for Georgia, 4.30 for Wyoming, 3.58 for Virginia, and 3.56 for Rhode Island. The mean values collected for solidarity perceptions by accent were 2.67 for Georgia, 3.90 for Wyoming, 3.52 for Virginia, and 3.22 for Rhode Island. Two single-factor ANOVA tests with alpha values of .05 were conducted and returned p-values of 4.97×10^{-25} (intelligence ratings) and 1.96×10^{-13} (solidarity ratings). Post-hoc Tukey tests showed statistically significant differences between every group except Virginia and Rhode Island's intelligence ratings. These data did not support the research hypothesis that that if high-school-aged Central Virginian listeners were presented with different recordings of speakers using Rhode Island, Georgia, Virginia, and Wyoming American English accents, then the listeners would rate the speaker with the Virginia American English accent as being the most intelligent and having the most solidarity with themselves. In conclusion, speaker accent had significant effects on listener perception of speakers, but listeners were not necessarily biased towards their home accent.

Second Place

Katherine Peterson - Effect of Music Genre on Working Memory
Central Virginia Governor's School

This study investigated whether preference for a type of music genre played during a studying period had any effect on the scores of a memory test. The hypothesis stated that if individuals were exposed to a music genre that they enjoy, then they would have an increased score on a visual memory test. Each one of seven participants completed three trials where they studied a variation of the test sheet while listening to their selected preferred music, non-preferred music, or silence. A five-minute time interval passed before they were asked to recreate the original test sheet, which was made of colored geometric shapes and words. The test sheets were compared to the original and scored based on accuracy of position, shape, and color of objects arranged on the pages. A single-factor analysis of

variance test found that there was no significant difference between groups because the p-value of .74 was greater than the alpha value of .05. This means the data did not support the research hypothesis because the null hypothesis was retained. These findings contributed to the ongoing study of memory and the effect of music on mental functions through testing the effect music played during a study period had on a memory test.

Third Place

Laila Gwathmey -The Effects of Age and Distance on Your Color Cognition
Chesapeake Bay Governor's School

Color is used in everyday life. It's used to figure out what you are wearing or how you can tell the difference between night and day. Being able to process how you see color is called color cognition. Color cognition differs based on your age. The older you get, the harder it is for your brain to process basic colors. As a person grows, their eyes begin to become farther from their brain causing it harder to see certain things, this is why seniors tend to need visual aids, such as glasses. This study compared how a person's age can affect how they can see an object based on its contrast level (high, low and no contrast) and secondly how distance can affect how a person can identify an object. A test was given to 40 participants (20 teens and 20 seniors) to test this theory. There were 9 posters with different contrast of objects (3 low contrast, 3 high contrast and 3 colored) and each participant had to stand with their back to a wall. While the participant was standing there, each poster was shown at distances of 5 meters, 10 meters and 20 meters. It was hypothesized that the teens would have a greater chance of recognizing an object based on the objects contrast and the shorter distances would have a greater amount of correctly identified objects. The study found statistically significant differences in teen and senior data, comparing color contrast and the time taken to recognize an object, but not between each group for the distances. It can be inferred from this study that teens have a greater chance of viewing and understanding colors based on objects contrast than the seniors can. While on the other hand, seniors try to process their what their seeing faster causing them to have a disadvantage in understanding what they see.

Honorable Mention

Eva Le -The Effect of Language in Music on High School Students' Focus Ability
Central Virginia Governor's School

The purpose of this study was to determine whether or not the language of a song has a significant effect on a student's focus ability. Participants recruited through two local high schools went through four different trials which consisted of taking a short-term word recognition test with The Beatles' "Hey Jude" playing in the background in different languages (English, Japanese, German, and with no music as a control group). The score they received after each test was measured in points. The results did not show a significant difference between the data. This did not support the

research hypothesis which stated that if students take a short-term word recognition test while listening to the Beatles' "Hey Jude" in different languages, they would score higher with the Japanese version playing compared to other versions. To test the hypothesis, data sets were run through six different paired t-Tests which compared each variable to each other. Each test generated a p-value higher than the .05 alpha value that was used (.593, .322, .457, .493, .799, .608). The results suggest that music in different languages does not have an effect on focus ability.

Honorable Mention

Claire Whaley - How Music in Different Keys Can Comparatively Help to Reduce Stress Levels
Central Virginia Governor's School

The purpose of this experiment was to improve the overall health and well-being of students by examining how music in different Keys can comparatively reduce stress levels in teenagers. To perform this experiment, local high school students were recruited to participate, who then listened to specific song compilations grouped by Key. They filled out pre and post surveys ranking their stress and answering background questions about specific stressors to gauge the effect of listening to music in certain Keys. This occurred once a week for four weeks. In order to analyze the results of this data collection, paired t-Tests were performed on each Key group. The C Major p-value was .005 and the A Minor group had a p-value of .044, which are both statistically extreme values when compared to the alpha value of .05. The average change in stress levels was -1.307 in the C Major group and -.769 within the A Minor group. On the other hand, the F Major group had a p-value of .201 and the Silence group had a p-value of .193, both of which are greater than the alpha value .05, and thus insignificant data sets. The research hypothesis, which stated that C Major would significantly reduce stress levels in students over other Key and Silence, was partially accepted. The hopes were that the results of this project, paired with previous, related research, could be used to help people to strategically pick music to help them with anxiety, and other mental illnesses or disorders.

Honorable Mention

Ryan Gheen -The Effect of Social and Economic Political Extremity on Conspiracy Beliefs
Central Virginia Governor's School

The purpose in conducting this study was to gather more data on how political affiliation and extremity of views affect conspiracy beliefs. Reddit users were asked to complete a Google Form survey that had them answer questions from The Political Compass Test as well as other questions for added information. From ten total responses, a mean economic value of -5.32 and a mean social value of -5.73 were gathered from participants' results in The Political Compass Test. A two-sample t-test was conducted on the data looking for a significant difference between economic and social values. In the test, an alpha value of .05 was used, and a p-value of .975 was produced, indicating no

significant difference. In conclusion, this study did not find any significance, and the research hypothesis that political extremity increases the likelihood of conspiracy thinking in an individual was not supported. This research shows that conclusions about factors influencing political ideology and conspiracy theories are hard to draw without a significantly large sample size.

Jenny Zhang -The Effect of Parental Separation on how Their Child Will be in Interpersonal Relationships
Central Virginia Governor's School

The purpose of this study was to determine how different marital statuses influenced their child's behavior in interpersonal relationships. This study was conducted at a local university during November of 2022. A Google Form Survey was sent out with each response selecting either they grew up with both biological parents or with one parent (other). In the Google Form two surveys were presented: the first survey is Children's Perception of Interparental Conflict which measured levels of conflict properties, self-blame, and threat and the second survey derived from Sternberg's Triangular Love Scale measured levels of passion, intimacy, and commitment. The purpose of the first survey was to give more context as to why young adults answered the way they did in the second survey. The responses were scored using the total points method and the means of each category was analyzed using a two-sample t-test. The alpha level is set to .05. From the t-test, the p-value for commitment levels came out to be .172. This showed that the data was not statistically significant, therefore the research hypothesis which stated that if parental separation occurs, then the child will be involved in lower committed interpersonal relationships, was not supported. In conclusion, commitment levels did not fluctuate based on the parent's marital status.

Jordan Lucas - Will the Rate of Sexual Violence and the Resources a School Provides for It Influence Your College Decision?
Southwest Virginia Governor's School

Sexual violence is a global problem that can happen to a person of any age. Focusing on sexual violence at colleges and universities, this study considered the influence of sexual violence statistics on a high school student's college decision. A sample of 37 participants were surveyed twice, once before reading an information sheet and once after. The results were analyzed through a chi-squared test of homogeneity. Participants were asked the question "Do you think there are enough resources for sexual violence (reporting, prevention, counseling) at universities?" After reading the sexual violence information sheet, there was a significant increase in the number of participants that agreed there are not enough sexual violence resources at universities (p-value <.0051). It was also found that the majority of participants agreed that resource centers need more funding and that their college decision would be influenced by the sexual violence resources a school provides. Though these results were not statistically significant, it was notable that

the majority of high school students felt resource centers need more funding and that their college decision would be influenced by the resources provided. This study suggests that high schools should implement prevention programs for their high school students and that colleges should prioritize campus safety and resources.

IvyElizabeth Mann -The Effect of COVID-19 Quarantines on High School Student Extroversion
Central Virginia Governor's School

The purpose of this study was to further examine the changes between social patterns with high school students due to the COVID-19 pandemic, while providing a better representation of the increase in demand for mental health assistance in teenagers after government quarantines. The study was conducted through two surveys, one analyzing pre-COVID patterns and the other analyzing post-COVID, which were designed to show the extraversion of participants. These data were based on a five-point scale system and analyzed through a Paired t-test and one-way ANOVA ($\alpha = .05$). The p-values given by the tests were .157 and .56 respectively. The research hypothesis, that COVID-19 isolation resulted in lower levels of extraversion in teenagers, was not supported. The pandemic impacted society and it is important to continue to study changes of patterns and social structures in order to assess how impactful COVID-19 really was, especially psychologically.

Statistical Analysis & Inferences (HS SAI)

First Place

Statistics Award

Yash Saxena - Optimizing A Deep Learning Model for the Prediction of Electric Field Induced by Transcranial Magnetic Stimulation for Traumatic Brain Injury Patients
Maggie L Walker Governor's School

TMS is a non-invasive treatment for diagnosing and treating neurological and psychiatric disorders, such as depression. It is being tested as an experimental treatment for patients with TBI. TMS coils generate a magnetic field, inducing an electric field in the brain causing depolarization; however, because the brain is a complex structure, the induced electric field may not be of the correct strength at the intended location. Methods like FEA are used to determine the induced electric field but are time consuming. DCNNs were created with different model depths and color spaces in which induced electric field images were fed into them. MRI of 11 subjects with mTBI were taken and FEA simulations were performed to generate the anatomical and electric field images used for training the DCNN. Across all color spaces, the PSNR, which is a measure of correlation, increased as model depth increased. For the depth 5 RGB, LAB, and YCbCr models, the training PSNRs were 34.557 dB, 32.791 dB, and 34.006 dB respectively and the testing PSNRs were 28.431 dB, 28.578 dB, and 28.761 dB respectively. This paper applied the model in Tashli et al.'s paper to patients with mTBI using a dataset from TBI patients and increased the model PSNR by increasing the model's depth and by employing a different color space to encode the electric field image when training the DCNN, despite having used fewer images to train the models. With other papers, this project sought to investigate the efficacy of TMS in mTBI patients.

Second Place

Ankita Mandal - Prediction4Protection: A Mobile Machine Learning Web Application in the Prediction of Heart Disease
Mills E Godwin High School

Across the world, there are few universal scenarios, but the pain of losing a loved one to heart disease is an exception and a reality shared by millions every year. Heart disease is the greatest killer in society today, and one prevalent root of this issue is untimely diagnosis, often caused by the unsustainable costs and lack of accessible healthcare for

underserved populations. Recognizing these disparities, the goal of this project was to create an easily available application and interface for all that accurately indicate one's risk of heart disease. To address this, a machine learning model, Prediction4Protection, was built in Python. A dataset compiled of 1025 patients of diverse backgrounds was scaled, adjusted to include inquiries answerable by patients, and split into 75% train, 15% validation, and 25% test. Four models were tested with the hypothesis that if the RandomForestClassifier was used, it would have the highest validity. This was not supported as the Decision Tree model had 97% accuracy with an attention mechanism, verified by a one-way ANOVA of 0.0035 and sensitivity analysis. Through the application software Streamlit, this program was processed into a web application now found in browser extensions. The application reports the risk of one having heart disease and describes the risk percentage in developing heart disease within the next year. With a simple interface and high accuracy, Prediction4Protection aims to provide a view into one's health with the goals of accessible heart disease prediction and early treatment for patients around the world.

Third Place

Drew Goodove - Logistic Regression of State Governmental Regulatory Stances on Cryptocurrency
Ocean Lakes High School

One of the purposes of government is to protect its citizens. Sometimes that protection is not from something on a battlefield but rather from a computer. Cryptocurrency, along with other digital assets, is a financial innovation in the eyes of many lawmakers for its rapid, easy transactions and its capability for scams and frauds to thrive. There have been varying approaches to regulating cryptocurrency in the United States, and this study aims to understand the socioeconomic factors that influence these differences. This research considers non-violent crime rates, energy consumption, internet usage penetration, and political party affiliation (% registered Republican) across all 50 states to determine their statistical significance to cryptocurrency regulation using logistic regression. It was hypothesized that all of these factors, except political party affiliation, would have a significant effect on a state government's stance on cryptocurrency regulation, given the relative novelty and complexity of the topic. The analysis conducted using Rstudio, a statistical computer science server, found that only political party affiliation had a statistically significant effect on cryptocurrency regulation between states that regulate and do not regulate cryptocurrency, as indicated by a p-value of 0.0286. This research provides valuable insight for policymakers seeking to promote safe and effective regulation of cryptocurrency and highlights the importance of bipartisan support in developing potential legislation on the topic.

Honorable Mention

Isabel Kirkwood - How the Inaccessibility of Feminine Hygiene Products Affects Low-Income Communities
Central Virginia Governor's School

A variety of variables have impacted the accessibility of menstrual products in the United States over the last decade, especially in areas that have higher poverty rates. This study was conducted to determine how much individual income is spent on feminine hygiene products each year, and how these percentages can change with time. This was conducted over a period of one month using online censuses and articles to acquire the information needed. The poverty rates and average individual income in twenty American cities were tested, ten from the cities with the highest poverty percentage and ten from the cities with the lowest poverty percentage. These numbers were taken from 2016 and 2020 censuses for each city. Two paired t-Tests comparing the percentages from the cities with the lowest poverty rates from both years and the highest poverty rates from both years yielded p-values of 8.59254×10^{-5} and 1.3968×10^{-4} , respectively. A two-sample t-Test comparing the percentages from the cities with the highest and lowest poverty levels in 2020 concluded that there was a p-value of 2.74862×10^{-5} , while a second two-sample t-Test comparing the percents from the cities with the highest and lowest poverty rates in 2016 showed a p-value of 4.95434×10^{-6} . All four of these t-Tests had an alpha value of .05, which showed statistical significance in the data. This conclusion supports the research hypothesis that people in American cities with higher poverty rates would spend a greater percent of their income on menstrual products.

Honorable Mention

Daniel Lim - Can online schools replace traditional brick-and-mortar schools? Implications from the examination of the relationship between course modality (online vs. in-person) and the SOL pass rates of high schools in Virginia
Douglas Southall Freeman High School

In March of 2020, the world entered lockdown due to the pandemic caused by COVID-19. During that time, the overwhelming majority of students in the United States were forced to switch to online learning, where they had to stare at a screen for hours. The question arose, whether online learning was as effective as in-person learning. There had been no previous research on the effect of synchronous learning on academic performance, so this paper attempted to answer those questions by examining the most recent three SOL (the Standards of Learning) pass rates of high schools in Virginia, and the extent to which course modality is associated with the SOL pass rates of Virginia high schools and subgroups, such as race and gender. The author also explores whether course modality is differently associated with the pass rates of each SOL subject (reading, math, and science). After experimentation, the results suggested that online learning does have a negative impact on academic performance. When students switched from traditional in-person learning to online learning, there was a distinct drop in SOL score when observing different factors such as race, gender, as well as disabilities. These findings demonstrated that the online education system was not sufficient enough to replace traditional in-person learning and support the idea that online learning presents numerous obstacles to students who were used to attending in-person classes. In addition, this paper attempted to explore the influence of online learning on each SOL subject to shed light on which subject might be more or less suitable for online

learning, on the basis of the cognitive memory theory. The data was examined, revealing a specific pattern. The reading SOL pass rate was slightly negatively influenced by online learning, the science SOL pass rate was moderately negatively influenced, and the math SOL pass rate was significantly negatively influenced by online learning. Based on the cognitive memory theory, the findings implied that subjects such as English were more suitable for online learning, as the courses were planned to add on to existing knowledge and skill sets, compared to subjects that create new knowledge and skill sets.

Honorable Mention

Jackson Coleman -The Effect of Public Transit Ridership on Carbon Dioxide Emissions
Central Virginia Governor's School

The purpose of this study was to determine if the level of public transportation ridership in a United States state has a significant effect on the level of carbon dioxide (CO₂) emissions in that state. This study was conducted through data analysis in Microsoft Excel, using data from the U.S. Department of Transportation and the Environmental Protection Agency. I compared the unlinked passenger trips (UPT) per capita on public transportation in each state to CO₂ emissions per capita in each state. I used a correlational test with an alpha value of .05 and found an R-value of -.358. This R-value was greater than the critical value of .273, and thus, there was a significant negative correlation. This supported my research hypothesis that there would be a negative correlation between both variables. In summation, increased public transportation on a state level has a significant negative correlation on the resulting CO₂ emissions.

Hope Banks - Overdose Mortality Rates and the Correlation with Poverty Levels and Populations of Persons Drawing from SSDI or SSI in West Virginia
Southwest Virginia Governor's School

According to the Centers for Disease Control and Prevention (CDC), West Virginia has the highest overdose mortality rate in the United States of America. West Virginia's mortality rate is over 1.5 times higher than that of Kentucky, the state with the second-highest mortality rate (81.4 vs. 49.2 per 100,000). The motivation of this project was to discover if there is a significant correlation between overdose mortality rates and the poverty levels and populations of persons on disability insurance in West Virginia. The expected outcome for this project was that there is a significant correlation and that counties with higher levels of poverty and populations of persons with disabilities are at a higher risk of death by overdose. For this study, 2020 data were procured from the CDC, the United States Census Bureau, and the Social Security Administration (SSA). Data from the CDC and the United States Census Bureau accounted for numbers pertaining to estimated deaths by overdose per county, estimated death rates per state, and poverty rate per county in West Virginia. Data from the SSA accounted for numbers pertaining to persons drawing from SSI or SSDI. All data

were analyzed through a multiple linear regression model on JMP. For this project, all fifty-five West Virginia counties were analyzed. There was a significant correlation between the overdose rate and poverty rate, as well as the population living on disability. Poverty rate had a p-value of 0.0002 and population on disability had a p-value of <.0001-both under 0.05. The predicted RSquare adjusted was 0.5232. An equation for overdose rate was created analyzing the overdose rate, number of people living on disability, and percent poverty rate as a multiple linear regression:
Overdose Rate =
 $-13.8363 + 0.0171153(\text{Disability}) + 2.6620419(\text{Percent Poverty Rate})$.

Karstan Bock - Gamification on User's Accuracy and Efficacy on an Online Educational Tool
Ocean Lakes High School

In recent years there has been a downward trend in mathematical performance by students, particularly those in the United States. As such, modern pedagogy has emerged as a topic of debate where educators endeavor to uncover new strategies that will enhance student comprehension and retention of material. One new strategy is that of gamification, or the process of incorporating game-like elements into educational processes in an effort to increase student engagement and retention of material. This strategy was employed to meaningfully engage a target population of remediation algebra students. As such, the researcher set out to answer how users would respond to various methods of positive reinforcement on Acalympics, an online educational tool created by the researcher. The null hypothesis for this work is that changing the method of positive reinforcement, compared to the original method, does not impact user accuracy or efficacy and the alternative hypothesis is that changing the method of positive reinforcement, compared to the original method, improves user accuracy and efficacy. Results of the research were unable to reject the null hypothesis for user accuracy, meaning the data is statistically insignificant at determining whether the variation in user accuracy by method occurred purely by chance. User efficacy, or improved user response time, was ultimately not considered due to confounding variables. This research indicates the necessity of further research, particularly that of the entirety of an online educational tool's population in order to more accurately determine the effectiveness of specific gamification strategies at engaging individual users.

William Xiao - Accessibility to Urgent Care Services for Disadvantaged Populations an Analysis of Healthcare Disparities
Mills E Godwin High School

This study analyzed the accessibility of disadvantaged individuals in the Richmond Metropolitan Area to urgent care facilities. Healthcare is important toward an individual's well-being as well as the social and economic health of the community. Accessibility was defined as the shortest travel time between census zones. The census zones were

categorized by the percentage of disadvantaged individuals residing in them using k-means clustering. Three groups were made: FI (financially independent) minorities, poverty, and FI non-minorities. In this study, a disadvantaged individual was defined as anyone who was in poverty or a minority. It was hypothesized that zones with a higher percentage of disadvantaged individuals will have a longer travel time. A one-tailed t-test was conducted to compare accessibility score between groups. FI non-minority zones had the best accessibility score, then it was impoverished zones, and finally FI minority zones had the longest travel time. Most minorities resided in the city, being more congested than the suburbs, thus causing longer travel times and worse accessibility scores. Further research can be conducted by analyzing the travel time for ambulances to different zones. Additionally, the geographical scale can be increased to incorporate all of Virginia.

Ralitsa Hovanesian - Optimizing Cancer Identification and Prognosis based on DNA Methylation Biomarkers through Machine Learning
Ocean Lakes High School

With about 1.9 million new cancer cases diagnosed each year in the United States, the early classification and identification of such cancers are vital for accurate and potentially life-saving treatments. In recent years, liquid biopsy DNA methylation testing of tumor suppressor genes, specifically at CpG sites, has been popularized due to its ability to identify cancer epigenetic biomarkers and predict cancer prognoses correctly, and yet most unsupervised machine-learning systems struggle to provide optimal analyses of comprehensive patterns of methylation levels at candidate genes due to their highly dimensional properties. I investigated the use of data clustering and algorithmic filtration of such data to better analyze methylation levels in the BRCA2, EGFR, MSH6, and CEBPA genes. Hierarchical clustering of tumor tissue versus healthy human tissue was first done to obtain accuracy measurements of 98%, from which more specific clusters were separated and run individually through traditional K-mean clustering and Gaussian mixture-modeling, comparing the competence of both in optimizing cancer prognosis using Rand Indexing. A set of 3579 tumor methylation features were used from The Cancer Genome Atlas Program, recognizing that hypermethylation is often the driver behind oncogenesis and an indicator of tumor development. Overall, it was found that Gaussian mixture modeling was about 12.3% more capable of accurately identifying prognosis and survival rate than typical K-mean clustering methods when assessed against true prognosis results. Such algorithms provide a promising avenue to employ the insurgency of new methylation technology to better identify and diagnose various cancers, including leukemia, breast, lung, and colon cancer, to save lives in a more accessible method.

Shantanu Patel - Effects of COVID-19 on Mathematical Learning Among Multilingual Students
Independence High School

Mathematics is a big driver in addressing the world's complex problems, such as feeding a growing population, ethical use of artificial intelligence, and environmental sustainability. Previous research has established that due to the COVID-19 pandemic, many students suffered learning loss, particularly in math. The learning gap in math education due to the pandemic and socioeconomic inequalities will have long-lasting implications for many students, contributing to the lack of career opportunities and increasing income disparities. This study aims to understand the role of language in the mathematical performance of students who attended school virtually during the COVID-19 pandemic.

Eli Wiscarson - Comparing Giles to Other Counties by Location and Population
Southwest Virginia Governor's School

Giles County is a small county in southwestern Virginia. With a population of 16,787, many people look to this county for opportunity and safety. Within a population, there must be an understood standard of living, specifically with regard to income and health. The objective of this study was to determine whether or not Giles County met this standard by using counties of similar size and location. The counties were as follows: Bland, Pulaski, Montgomery, Craig, Buckingham, Appomattox, and Brunswick. Two counties were of West Virginia: Mercer and Monroe. The cities of Radford, Manassas Park, and Bristol were also used. To test whether or not Giles met the standard of living, data were found using the United States Census. After the data were collected, they were put into a one-sample T-test and compared against Giles's data. The null hypothesis was that Giles was not dissimilar to the other counties in the areas of health and income, and the alternative hypothesis was that Giles was outside the normal limits of the other counties. After the T-test was conducted, it was found that Giles was similar to the other counties, except that it had lower rates of obesity, adult smoking, and disability beneath the age of 65 than the other counties.

Alexis Cassell - Brand Name vs. Name Brand Products
Southwest Virginia Governor's School

In this study, name brand and generic brand products were sat side by side and teen participants were asked to choose their preferences. There were 6 products tested: Fruit Loops/Fruit Spins, Oreos/Twist and Shout Cookies, American Eagle leggings/Walmart legging, American Eagle T-shirt/Walmart T-shirt, Gain Flings/Great Value Laundry Pacs, and SOLO cups/Great Value Cups. This experiment was done in three different stages, the appearance, brand, and price stage. The appearance stage is where they just chose based on the looks, the brand stage where they were told the brand and chose again, and the price stage is where they were told the price and chose again. Data were analyzed using a Chi-squared test of independence. The null hypothesis was the product chosen and the descriptive characteristics are independent of each other, and the alternate hypothesis is the product chosen and descriptive characteristics are dependent on one another. There was a total of 32 participants tested and some of their answers

changed throughout the experiment. This showed that the way a product is described can influence decisions. Based on the statistical analysis, the null hypothesis would be rejected, and the alternate hypothesis would be accepted for all products except the t-shirts. For example, the p-value for the Fruit Loops vs Fruit Spins was 0.0005, so the null was rejected because it was less than 0.05. For the T-shirts the null failed to be rejected because the p-value of 0.2723 was greater than 0.05. This study was beneficial because the brand preferences in teens had yet to be studied in detail, while there have been many adult studies. This information can help predict what teens will buy later in life and help companies decide to make their own generic brands.

Zoology (HS ZOO)

First Place

VABE Zoology Award (Virginia Association of Biology Educators)

Rania Lateef - Food for Thought: Can Intermittent Fasting Induced Ketosis Ameliorate Dementia by Decreasing Tau Hyperphosphorylation and Neuroinflammation in *Drosophila melanogaster*?

Charles Colgan High School

Background: Dementia is a highly prevalent neuropsychiatric condition characterized by impairments in memory, reasoning, mood, and behavior. Yet it has no effective treatment that targets the underlying biochemical pathology. The main goals of this project were to utilize a *Drosophila melanogaster* model of Dementia and determine whether ketosis induced by intermittent time-restricted feeding (iTRF) can lead to decreased mortality, improved memory, and enhanced locomotor function. Methods: flies with the V337M Tau mutation were used as validated model of dementia. Both demented and control flies were subjected to either: (1) 24 hours access to food/ad libitum or ad lib OR (2) a Time Restricted Feeding (TRF) schedule with 10 hours of fasting during lights off and 14 hours of fasting, mostly during lights on. In order to assess the effect on lifespan, the percentage of flies surviving over time, within each group, was calculated. Impaired geotaxis, or loss of climbing motivation, was assessed as a measure of locomotor ability. The Aversive phototaxic suppression assay was used to assess learning/memory; flies learn to avoid light that is paired with an aversive stimulus. Group differences were analyzed with survival curves. Chi-square tests were used for the categorical variables. Results: Survival curve analysis showed that the flies subjected to iTRF for 4 days lived longer than flies who fed ad lib, with the effect being more pronounced among the dementia group. Flies with Dementia had impaired climbing ability compared with controls, but within each group, there was no significant difference in locomotor function, among those fed ad lib versus iTRF. Flies with dementia demonstrated significant impairment in short-term memory and learning compared to the control flies (p-value = 0.03). iTRF did not improve short-term memory among control flies (p-value = 0.55) but greatly enhanced memory and learning in the dementia group (p-value = 0.04). Conclusion: Intermittent Time Restricted Feeding, and associated ketosis may be a promising new intervention for Dementia. Future studies should evaluate the associated metabolic pathways as well as the changes in brain pathology that accompany improvement in clinical symptoms.

Second Place

Brett Smith -The Phylogenetic Relationship of Ctenophores with Respect to Other Basal Metazoan Clades

Roanoke Valley Governor's School

The enigmatic phylogenetic position of phylum Ctenophora compared to other Metazoa has long remained understudied and controversial. Discoveries regarding the phylogenetic position of Ctenophora may reveal positions of other related clades and the nature of evolutionary innovations of various complex systems now present in many Metazoan clades. In order to determine the effect of analyzed genes on suggested phylogenetic relationships, mtDNA and rRNA were collected from each included clade, and a consensus sequence was generated from each order using EMBOSS Cons and Clustal Omega. Toffee was used to generate multiple alignments of all consensus sequences for each gene, and the resulting trees were recorded and analyzed. Mitochondrial DNA sequences were pulled directly from chromosomes stored on NCBI. Ribosomal RNA sequences were found manually by using NCBI's Blastn tool to locate similar ribosomal nucleotides. Mitochondrial genes COX1, COX2, ND1, and CYTB were analyzed with Toffee resulting in trees highly suggestive of Acrosomata, a clade of Bilateria and Ctenophora. Non-mitochondrial ribosomal genes 18s (small subunit) and 28s (large subunit) were analyzed with Toffee and Clustal Omega respectively, resulting in data highly suggestive of the Ctenophora First or Porifera Sister theory. Clustal Omega was used to analyze 28s sequences as Toffee returned a generic error when attempting to process them, likely resulting in small data discrepancies. Phylogenetic trees from ribosomal RNA suggested the Ctenophora First theory without significant inaccuracies. In contrast, mtDNA suggested the Acrosomata theory, however, mtDNA-based trees were inaccurate compared to the current theory of Metazoan lineage.

Third Place

Rimil Chatterjee -The Effect of Various Microplastics on the Heart Rate of *Daphnia magna*

Mills E Godwin High School

The purpose of this experiment was to find the effects of various microplastics on the heart rate of *Daphnia magna*. In recent times, common plastics found in household products such as glitter, grocery bags, and packaging Styrofoam such as polyethylene and polystyrene have been used increasingly, causing the amount of microplastics found in aquatic ecosystems to rise significantly. The heart rates of *Daphnia magna* were measured after they were exposed to either glitter, grocery bag particles, or Styrofoam particles for three hours. The control used in the experiment was no added microplastics. It was hypothesized that *Daphnia magna* exposed to glitter would have higher heart rates compared to other experimental groups. The results of the experiment showed that *Daphnia magna* exposed to plastic particles from a grocery bag had a higher average heart rate than the remaining experimental groups and control. Multiple t-tests were done on the collected data, and it was found to be significant for all the independent variables except for the Styrofoam particles versus the control. The observed results did not support the research hypothesis. It is speculated that the results are due to the differences in chemical composition of the different experimental groups and how the plastic grocery bag floated in the water, remaining closer to the *Daphnia magna* compared to the other

experimental groups, which sank over time. The research conducted in the experiment could lead to further investigations on differences in size of microplastics and their effects on *Daphnia magna* heart rate.

Honorable Mention

Aditya Badhryan - Analysis of Aspartame Consumption Rates via *Drosophila melanogaster* Utilizing a Modified Capillary Feeding Assay (CaFE)

Maggie L Walker Governor's School

Artificial Sweeteners, also known as Non-Nutritive Sweeteners (NNS) have become an essential part of diets across the globe. By providing fewer calories with a higher intensity of sweetness, they are used by a variety of demographics for reasons such as obesity reduction, alternatives for diabetic patients, and much more. Out of the six NNS agents deemed safe by the United States Federal Drug Administration, Aspartame has grown widely, notably in beverages and foods that promote alternatives to sugar. While claiming to aid in diabetic health and weight loss, there is a significant lack of research regarding the effects of the sweeteners on the consumption rate, possibly leading to an increase in health issues for diabetic patients and those looking for Aspartame as a healthier alternative to Sucrose. To investigate, *Drosophila Melanogaster* was used as a model organism. Due to similar processes with insulin production in *Drosophila* through the release of *Drosophila* Insulin-Like Peptides (DILPs) and the presence of Taste Receptors, the *Drosophila* was ideal for the testing and analysis of the consumption rate for Aspartame when compared to sugar. A unique and modified Capillary Feeding Assay was specifically designed for testing the consumption of liquid food of *Drosophila*. 4 different types of solutions were given, a high-concentration, medium concentration (based on the average Aspartame concentration in beverages), and a low concentration of Aspartame based solutions, as well as a control of a Sucrose based solution. The results astonishingly displayed an average of a 1.5x increase in mL of Aspartame solution consumed per fly compared to Sucrose over a 24-hour period, proving the research hypothesis. Interestingly, there was no significant difference between the high concentration and medium concentration of Aspartame; however, there was a substantial difference between the low concentration and the medium concentration of Aspartame. Regardless, the Sucrose solution was extremely low in consumption per fly over 24 hours. Due to the similarities between *Drosophila* and humans in regards to insulin production and taste receptors, the results clearly indicate that nourishment containing Aspartame can lead to a substantial increase in the consumption of a particular substance, causing an increase in the amount of unnecessary insulin being produced; which leads into more harm for diabetic patients and increased risk for obesity.

Honorable Mention

Shriyaa Anand -The Effect of LED Lights on the Hatching Rate of Artemia

Mills E Godwin High School

This experiment aimed to find the effects of different colored LED (light-emitting diode) lights on the hatching rate of Artemia. Although they have a generally high hatching rate, around 20% of Artemia eggs do not hatch. This can be an issue in habitats where light is limited. Recently, red, blue, and green LED lights have been used to understand what causes Artemia to hatch faster. The artemia eggs were exposed to the different colors of light for seventy-two hours, with a check in done in 6-hour intervals. To keep the eggs uninfected and prevent contamination, all testing areas were sanitized and cleaned before and after the testing time. The control that was used in the experiment was white LED light. It was hypothesized that if the eggs were exposed to the red LED light, the hatching rate would increase and be higher compared to blue and green LED light, and the results did not support the hypothesis. A t-test was done on the data, and it revealed that the data was significant for blue light versus control, red light versus blue light, and blue light versus green light. However, the data was not significant for the green light versus control, and green light versus red light. Nevertheless, the results did not support the research hypothesis. It is believed that the results are because white light results in the eggs hatching and obtaining a larger mass. This research could lead to future studies that investigate the effects of different types of light on the hatching rate of other aquatic animals and organisms.

Honorable Mention

Madison Nally, Ellie Kim & Fayza Mehrin - Feasting Fruit Flies: Evaluating the Effect of Selected Ayurvedic Plant Extracts on the Mood, Memory, and Fertility of *Drosophila melanogaster*.
Governor's School @ Innovation Park

Despite 80% of India's population incorporating Ayurveda to maintain their health, popular Ayurvedic herbs consumed to treat depressive moods, impaired memory, and infertility lack evidence to support their effectiveness. This study investigates the effects of Ashwagandha, Shatavari, and Brahmi on *Drosophila Melanogaster*'s: 1) Mood 2) Memory and 3) Fertility (n=20). Select percentages of each herb (2.5%, 5%, and 10%) were incorporated in fly medium to model human dosages. An impaired geotaxis assay was assessed to measure depression-like state. An aversive phototoxic suppression assay was conducted to evaluate short-term memory. Adult and death counts were conducted after a 2-week period to analyze fertility. Geotaxis was not significantly impaired by Shatavari, however, it was significantly impaired by Ashwagandha with the least optimal concentration of 10% (OR 0.03, $p < 0.001$). Geotaxis was positively affected by Brahmi with an optimal concentration of 10% (OR 7.43, $p < 0.02$). Memory was not significantly impacted by Shatavari (OR 1.11, $p > 0.05$), however, it significantly increased with consumption of larger concentrations of Brahmi (OR 3.99, $p < 0.05$). Ashwagandha positively increased memory with an optimal concentration of 10% (OR 3.67, $p < 0.02$). Fertility significantly increased at 2.5% Ashwagandha and Shatavari ($p < 0.009$, $p < 0.01$) whereas Brahmi decreased exponentially. Concentrations above 2.5% lowered fertility below control - Brahmi being most significant ($p < 0.004$), then Shatavari ($p < 0.006$). Ashwagandha did not decrease significantly. Overall, Ayurvedic herbs must be

scientifically reviewed as some negative effects on aspects 1, 2, and 3 are significant enough that they may endanger consumers. Despite exhibited benefits, they must be further substantiated to ensure safe usage.

Honorable Mention

Melody Ngo -The Effect of Aspartame on the Feeding Rate of *Daphnia magna* Exposed to an Appetite Suppressant
Mills E Godwin High School

The purpose of the experiment was to find if an artificial sweetener, aspartame, would have an antagonistic effect with the appetite suppressant *Garcinia cambogia* on *Daphnia magna*'s feeding. The use of appetite suppressants for weight control has increased, and they will become an aquatic pollutant. Freshwater ecosystems need filter-feeding *Daphnia* to clean water. Last year's experiment revealed *Daphnia* decrease feeding when exposed to *Garcinia*. It is believed aspartame will counteract *Garcinia* and be a solution to the future pollutant. *Daphnia magna* were fed *Nannochloropsis* green algae and exposed to 0 mg/L *Garcinia* and aspartame, 5 mg/L *Garcinia*, 10 mg/L aspartame, and 5 mg/L *Garcinia* with 10 mg/L aspartame. A SpectroVis recorded *Daphnia*'s algae consumption after 24 hours. The control was 0 mg/L *Garcinia* and aspartame. It was hypothesized aspartame would counteract the suppressive feeding effects of *Garcinia* on *Daphnia*. The mean results showed *Garcinia* decreased while aspartame increased feeding. The two combined brought feeding between the control and aspartame's results. A t-test revealed all data was significant except for 10 mg/L aspartame vs. 5 mg/L *Garcinia* with 10 mg/L aspartame. The results supported the research hypothesis. *Garcinia* was a toxin that decreased feeding through increased serotonin, stimulation of glucoreceptors, and impaired coordination. Aspartame was a stimulant that increased feeding through sweet taste receptors, a reduced reward pathway, and a sweetness to calorie imbalance. When combined, aspartame reversed *Garcinia*'s effects. This research should lead to further studies on *Daphnia* health and long-term aspartame exposure to help find solutions to decreased filter-feeding.

Bridget Blaszak -The Effect of The Herbicides Diuron and Bromoacyl on the Survival Rate of Marine Tardigrades in a Saltwater Solution
Mills E Godwin High School

The purpose of this experiment was to examine the effects of the herbicides diuron and bromacil on the survival rate of marine tardigrades. Diuron and bromacil are photosystem II herbicides that have been discovered in high concentrations in the oceans. A research hypothesis stating that if marine tardigrades are exposed to diuron, then all tardigrades will exhibit the characteristics associated with death after 24 hours. 3 solutions, one containing diuron, one containing bromacil, and the last, the control, contained no herbicide were created and placed in the environment of the tardigrades. After 24 hours had passed, the specimens were categorized as "death" or "survival". The results

of this experiment indicate that marine tardigrades that were exposed to diuron or bromacil are more likely to die, as the mode survival rate for the both the specimens exposed to diuron and the specimens exposed to bromacil was 50%. A chi-square test affirmed that the data was statistically significant. However, the results only partially supported the research hypothesis. It was concluded that diuron and bromacil have a negative effect on the rate of survival rate of marine tardigrades. This experiment could be continued with the study of the effects of the herbicides in humans, a more complex model.

Victoria Callahan -The Effects of Caffeine and Caffeine Withdrawals on Reaction Time
Central Virginia Governor's School

The purpose of this experiment was to determine whether caffeine and caffeine withdrawal has a significant effect on reaction time. This experiment was conducted in a local high school laboratory during November of 2022. Planaria were randomly divided into three groups of 15. One group was kept in spring water, one had caffeine mixed in with the spring water, and one was withdrawn from the caffeine. After a week, they were tested using a light stimulus test. The time it took the planaria to make it to the shaded side was measured in seconds. The mean time it took for the control group was 39.5 seconds, the mean time for the caffeinated group was 29.4 seconds, and the mean time for the withdrawn group was 59.4 seconds. A one-way ANOVA, with an alpha level of .05, showed a p-value of 1.338×10^{-7} . This statistically significant value supported the research hypothesis, which was that caffeine will speed up reaction while withdrawal will slow it down. In conclusion, caffeine and lack thereof has a significant effect on reaction time.

Samantha Lionberger -The Effect of the Color of Light on the Intensity of *Tapetum lucidum*
Mills E Godwin High School

This experiment investigated which color of light produced the brightest reflection from the tapetum lucidum of cow eyes, which would allow car manufacturers to better enhance car headlights and therefore safety. The hypothesis stated that if white/yellow light were used, then it would have the highest average lux (lumens/meter²). The control of the experiment was the white/yellow light group due to its already existing popularity in car headlights. After covering a flashlight in colored cellophane, the light was shown on 25 cow eyes per experimental group and the lux was measured by a lux meter app. After experimentation, it was concluded that the hypothesis was not supported by the data because the experimental group with the highest average lux was the green light group (79 lumens/meter²). The t-tests performed concluded that the data from the red light and the blue light groups had a less than 5% chance that the data was a result of chance or error. On the contrary, the t-test for the green light group concluded that there was more than a 5% chance that the data was not due to the independent variable. In conclusion, the green light was the most effective in making the tapetum lucidum shine brightly. The most likely reason for this was the minuscule changes in distance between the flashlight and the cow eyes. A way to improve this experiment would be to use eyes from

other animal species, which would mimic additional wildlife that drivers encounter.

Aarush Rudraraju -The Effect of Amino Acids on Microplastic Consumption rate by *Daphnia magna*
Mills E Godwin High School

The purpose of this experiment was to observe the effects of various amino acids on the microplastic consumption rate by *Daphnia magna*. Nowadays, growing industrialization is causing manufactured plastics to degrade into a plethora of microscopic particles called microplastics. Moreover, finding methods to decrease the abundance of toxic microplastics is imperative to environmental sustenance. Disregarding its fatality, *Daphnia magna* consume microplastics and their feeding behavior is affected by amino acids. To find the most potent amino acid, *Daphnia magna* were treated with either the amino acid L-Glutamine or L-Aspartate. Afterward, microplastics were placed in the *Daphnia magna*'s container. At the end of the five-day observation period, the microplastics were filtered out and weighed to determine the consumption rate. It was hypothesized that *Daphnia magna* treated with L-Glutamine would consume the most microplastics. The control of the experiment was the group of *Daphnia magna* where no amino acids were present because it causes standard feeding behavior. The results displayed that *Daphnia magna* treated with L-Glutamine ate, on average, 0.07 grams more than *Daphnia magna* treated with L-Aspartate and 0.08 grams more than *Daphnia magna* treated with no amino acid. A t-test performed on the data revealed that the results were significant and supported by the research hypothesis. The results likely occurred because the neutral L-Glutamine delivers a more habitual and food-like charge to the *Daphnia magna*'s gut resulting in a greater chemosensory input and natural feeding behavior than the negatively charged L-Aspartate. For continued research, investigating the effects of different amino acids on other organisms should be investigated.

Jenny Vu - Planarian (*Dugesia dorotocephala*) Memory Retention after the Removal and Regeneration of the Cerebral Ganglia and Various Percentages of Body Tissue
Ocean Lakes High School

Planaria flatworms (*Dugesia dorotocephala*) possess the ability to continuously regenerate their bodies, and their simple anatomy and extraordinary pluripotency have made them model organisms for cellular research. In this study, planaria worms were conditioned, bisected, regenerated, and tested for memory to investigate the planaria's capability to retain memories after regrowing their brain and various percentages of body tissue. It was hypothesized that *D. dorotocephala* would display memory retention after the removal and regeneration of their cerebral ganglia and various percentages of body tissue. Planaria groups were conditioned to associate either rough-bottomed treatment dishes or smooth-bottomed control dishes with food. After the removal of the cerebral ganglia and various percentages of body tissue, the worms regenerated. Then, all the planaria were tested in rough-bottom dishes to see if the familiarized

treatment worms would approach the bait more quickly due to their retained knowledge of the rough-bottom environment. After analyzing the data using a one-way ANOVA test, for the worms that regenerated ~10% of their body tissue, the control worms initiated feeding within 947.6 seconds on average, and the familiarized worms initiated feeding within 340.6 seconds on average, displaying significant ($p=0.0004$) memory retention. For the worms that regenerated ~60% of their body tissue, the control worms initiated feeding within 1091.8 seconds on average and the familiarized worms initiated feeding within 441.6 seconds on average, displaying significant ($p=0.0108$) memory retention. Though there was greater variability and a greater standard deviation in the control group data, there was not a significant overlap in the time taken to initiate feeding between the control and treatment groups. This indicated a significant difference, as the treatment group planaria were able to remember their feeding environment even after the removal and regeneration of their brain and up to ~60% of their body tissue. For decades, memory studies have been focused on the cerebral synapses, but the planaria's ability to retain memory after the removal of their cerebral synapses further emphasized the role of epigenetics in understanding memory. Also, the addition of information on the memory retention of *D. dorotocephala* could be supplemental to the understanding of pluripotency and evolution. The next steps would be to identify where memories are stored outside of the brain, and how memories are transferred during mitotic activity.

Special Interest Awards

Cancer Research Awards

1. Mercy Akanmu - Differences in the physical and structural changes during microglial activation in pediatric and adult glioma models.
Blacksburg High School
2. Zachary Schwehr - Brain Tumor Segmentation and Classification Based on Deep Learning, Attention Mechanisms, and Energy-Based Uncertainty Predictions
Mills E Godwin High School
3. Aashka Shah - Studying the Role of Epigenetic Regulators in the Recovery of Triple-Negative Breast Cancer
Maggie L. Walker Governor's School

Dr. & Mrs. Preston H. Leake Award in Applied Chemistry

Ariya Patel - A Novel Lateral Flow Immunoassay for the Detection of Parvovirus B19 Antigens in Urine
Southwest Virginia Governor's School

Roscoe Hughes Genetics Award

Ralitsa Hovanessian - Optimizing Cancer Identification and Prognosis based on DNA Methylation Biomarkers through Machine Learning
Ocean Lakes High School

Dr. Smith Shadomy Infectious Diseases Award

Janvi Spahr - The Effect of Pandemics on Life Expectancy in Different Regions of the World Since 1950
Washington-Liberty High School

Gamma Sigma Delta Award

Nicola Beaumont - The Effect of Salinity on the Growth of Chlorella
H-B Woodlawn Secondary Program

Speleological Society Award

Evelyn Ortuno - Finding a Buffer Solution to Protect Limestone from Acidic Rain
Washington-Liberty High School

Virginia Museum of Natural History Award

Olivia Cozette - The Effect of Different Locations of the Susquehanna River relative to the Conowingo Dam on the Concentrations of Different Chemicals
Washington- Liberty High School

Virginia Sea Grant

Kayleigh Miller - The Impact of Shoreline Hardening on Nearshore Fish Populations
Chesapeake Bay Governor's School

Scholarships

Bethel High School Scholarship

Erika Milhorn - The Effect of Vertical Oscillation and Cycles per Minute on the Effective Detection of a 24 GHz Device
Central Virginia Governor's School

Henry W. MacKenzie Environmental Scholarship (VEE)

Erik Graulich - The Effect of Biocide Type and Concentration on Hull Fouling and Exposed Estuarine Crustaceans
Chesapeake Bay Governor's School

Frances & Sydney Lewis Environmental Scholarship (VEE)

Julissa Valdez - Comparing Detergents Impacts on Brine Shrimp Hatching and Survival
Chesapeake Bay Governor's School

VJAS Honors

Dorothy Knowlton Award and Outstanding Research Project, Grade 7

Saanvi Sambangi - The Effect of Different Soaps on Bacteria Inhabiting the Hand
George H Moody Middle School

Joyce K Peterson Award and Outstanding Research Project, Grade 8

Ishan Shah - Comparing the Solubility of Brand vs Generic Allergy Medications in Hydrochloric Acid with pH similar to
Stomach Acid
George H Moody Middle School

Jones/Ellett Award

Philip Naveen - FASFA: A Novel Next-Generation Backpropagation Optimizer
Mills E Godwin High School

VJAS Grand High School Award, Grades 9-12

Erika Milhorn - The Effect of Vertical Oscillation and Cycles per Minute on the Effective Detection of a 24 GHz Device
Central Virginia Governor's School

Distinguished Service Award

Dr. Philip Sheridan

VAS Executive Officer

Franklin D. Kizer Distinguished Service

Michele Lombard

Arlington Public Schools

Franklin D. Kizer Teacher of Tomorrow

Matt Togna

Collegiate School

Outstanding Service Volunteer of the Year

Michael Lovrencic

Vice Committee Chair VJAS

VAS Honorary Membership

Hamza Arman Lateef – Governor’s School @ Innovation Park
Laasys Konidala - Mills E Godwin High School

VJAS Delegates to AJAS

Erika Milhorn
Central Virginia Governor's School

Abstract

The purpose of this study was to determine if changes in ground contact time, vertical oscillation, and cadence (z-axis movement) had any effect on the detection ability of a 24 GHz radar device. A machine was built to mimic a runner's motion using these three variables. Data collection took place on a flat road with cones set up at one-meter intervals from 130 meters to 150 meters. The data was compared to two controls, one found during data collection and the other was the outermost range of the device. There were five testing groups with 25 trials in each. The groups were compared to the controls using two ANOVA statistical analysis tests. The p-value for the found control was .014 and the p-value for the given control was 2.7E-09. Both of these were below the alpha of .05 establishing a statistically significant difference among groups. A post-hoc Tukey test was then performed demonstrating each group, when compared to the controls, had significance when compared to the Dmin values. The research hypothesis was supported because each of the five groups had 95% detection ability when exhibiting z-axis motion beyond 140 meters. This research demonstrates the plausibility of using a radar detection device for the safety of pedestrians along roadways.

Introduction

Over the past decade the number of total traffic deaths has increased by 13% while pedestrian deaths have increased by 54% (Sinder, 2022). The increased number of pedestrian deaths is alarming as most of these deaths, 67%, occur in daylight conditions and in areas with no sidewalks, an increase of 64% over a four-year period (Sinder, 2022). The national pedestrian death rate has increased steadily over the past ten years, from a rate of 1.39 pedestrian fatalities per 100,000 in 2009 to 1.91 in 2019 (National Highway Traffic Safety Administration [NHTSA], n.d.).

Cars are evolving from loud fossil fuel burners to quiet battery powered vehicles. While this creates many benefits, the lowered noise levels raise concerns as pedestrians are not able to

properly detect approaching vehicles from a distance. This concern is exacerbated because many pedestrians are near the flow of traffic. To help reduce the risk of potential pedestrian deaths due to quieter vehicles, the NHTSA introduced new requirements for electrical and hybrid vehicles in 2016 called “Federal Motor Vehicle Safety Standards; Minimum Sound Requirements for Hybrid and Electric Vehicles” requiring these vehicles to produce a noise while traveling below 19 miles per hour (mph) (NHTSA, 2016). Since this new requirement only addresses speeds below 19 mph, pedestrians may need to take further action keep themselves safe while on roadways.

Several methods used by pedestrians to take preventative action are to be more visible and follow road safety rules, such as walking against traffic. Walking against traffic reduced the likelihood of being struck by a vehicle by 77% (Luoma et al., 2013). Additionally, wearing brightly colored or reflective clothing is encouraged as it makes pedestrians 46% more visible than when wearing black or darkly colored clothing (Rosenberg & Laura, 2010). Even as pedestrians follow these safe practices, pedestrian deaths continue to rise as drivers become more distracted.

Similar to pedestrians, cyclists have comparable concerns with vehicles. Along with wearing bright colored clothing and increasing awareness of surroundings, cyclists have incorporated other visual aids such as flashing front and rear lights to help identify them to vehicles (Klaus, 2004). However, accidents continue to persist and this was recognized by a pioneering company. Garmin, a sports tracking company is a leader in GPS navigation and wearable technology for the outdoor and fitness market, developed and released a rearview radar device with a flashing tail light that communicates to a cycling computer on the rider’s handlebars. This radar device detects and notifies the cyclist via sound and visual display, of approaching vehicles as well as the approximate distance the vehicle is away from the cyclists. This advanced notification allows for a potential of reduced vehicle strikes because the cyclist is better prepared for the approaching vehicle and makes necessary adjustments (Dorn et al., 2022).

The device currently used by cyclists to detect vehicles behind them is a Garmin Vavia radar device, which uses a frequency-modulated continuous wave radar. Would this same device be able to work on a runner? Runners exhibit a very different range of motion than cyclists, who have a smooth z-axis motion as opposed to the semicircle pattern motion of runners. There are five different groups of runners categorized by Garmin, each with their unique pattern of vertical

oscillation (VO), cadence (rpm), and ground contact time (GCT) that makes up a different semicircle (Garmin, n.d.a & Garmin, n.d.b). This leads to my research question: If the 24 GHz Garmin Vavia moves in the z-plane (up and down, and at different rates per minute with pauses at the top and bottom), would the 24 GHz Garmin Vavia device still be able to detect an oncoming object, at 140 meters away, while the device is moving in different testing scenarios based on five average groups for runners.

I hypothesize that with the five groups in different ranges of motion, the device will be able to detect an oncoming object with greater than 95% accuracy. I did a one-sample ANOVA test because there is only one variable, as VO, rpm, and GCT change together, acting as one variable. The alpha value for this test is .05. The independent variable is the device's movement along the z-axis, and the dependent variable is the detection of the object. There are two controls, one from Garmin data and the other found during testing.

The concepts necessary to understand this project are incline crank, vertical oscillation, the radio frequency (RF) spectrum, Frequency Modulated Continuous Wave Radar (FMCW) radar, SNR signal to noise, A to D converters, Voltage Control Oscillator, noise, range resolution, frequency shift, bandwidth, chirps/beacon, and velocity resolution.

The primary technology behind this device is 24GHz Frequency Modulated Continuous Wave (FMCW) radar. An advantage of using this type of radar signal modulation is it can measure the target object's range and velocity simultaneously allowing for “real-time” notification. Another advantage is its good performance in a variety of weather and atmospheric conditions such as heavy rain, fog, dust, and the effects of temperature differences; which varies from other types of radar such as millimeter-wave radar systems which are prone to detect ghost objects as moving targets because of the sensitivity to light and motion (Will et al., 2019). The Garmin Varia Radar device can detect objects and measure velocities at distances up to 140 meters at a speed of 10 km/h to 160 km/h (Krejci & Mandlik, 2017). Even though the Garmin unit was released in 2015 and has gone through many different design iterations, Garmin has yet to incorporate this technology into any products for pedestrians.

There may be several reasons why a pedestrian form of this product has not been released. These reasons could be the market acceptance, core technology capability, or human health and safety concerns from radio frequency (RF) exposure. The core technology influences the size of the device, if the device could not be miniaturized, most runners would not accept a large or heavy device attached to them while running leading it not to be accepted by the target

market. Another possible issue with the core technology could be its inability to adequately perform with the complex movement pattern of a runner. For cycling, the device is fixed in a stationary position on the seat post of the bicycle, and the mounting configuration limits movement on the z-axis. For running, the device would be attached to the body and would be in constant movement in all three (x, y, and z) axes. Movement makes distinguishing velocities between non-moving objects and moving objects more difficult (Hägelen et al., 2019). The runner's movement could cause a high multipath environment as well as problems determining velocity. Multipath reflections from objects, like the road's surface, becomes a problem as it is in the same direction as targets, and can be difficult to factor out (Villeval et al., 2014). These multipath reflections from objects result in the radar devices falsely detecting a moving target. Another factor for why a pedestrian product has not been released is RF exposure. Water in the human body readily absorbs this wavelength of energy and 95% of the energy is absorbed by the first millimeter of skin, causing burns (Balzano et al., 1995).

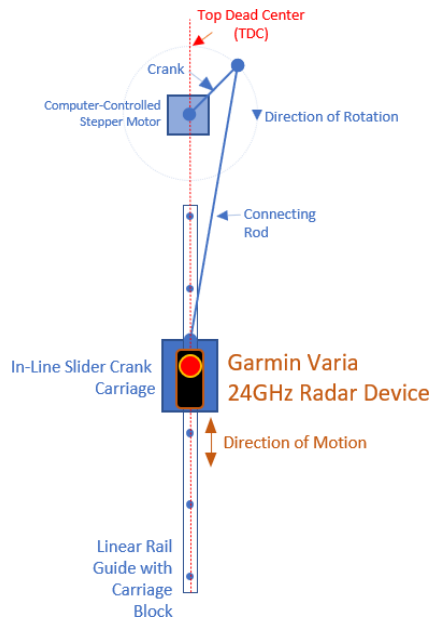
The purpose of this study is to investigate if the core technology and the radar device is capable of object detection for pedestrians users while in motion. Due to the limitation of time and resources, the study will only focus on motion effects in the z-axis. The study will test the Garmin Varia 24 GHz radar device across a range of z-axis lengths corresponding with different groups of runners based on biomechanical movements. This project requires knowledge of physics to develop and build a kinematic model capable of different test cases as well as the understanding of FMCW radar and the potential influences of its uses. Both of these areas relate directly to STEM fields.

Material and Methods

The testing apparatus consisted of a machine built out of plexiglass mounted on a sheet of plywood with a power supply, stepper motor, and Raspberry Pi. The stepper motor controller and computer code were used to control the machine to ensure the motion in the z-axis was precise and predictable. Stepperonline closed loop stepper driver and motor with 2 Nm of torque, <1.8 degree steps (200 steps to one rotation), and 5,000 rpm was used because of the power and torque capabilities.

Figure 1

Blueprint for in-slider crank machine

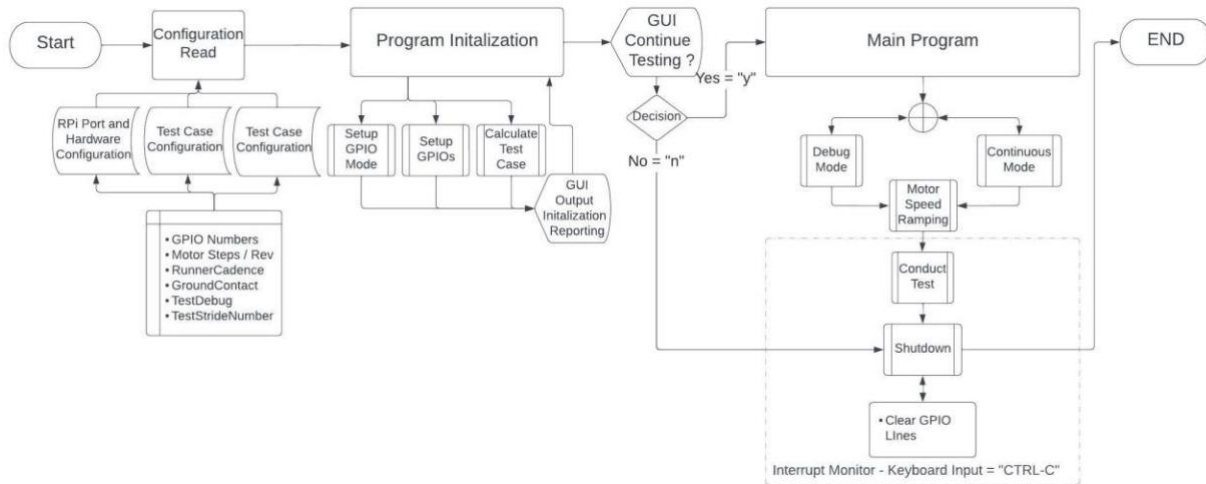


The machine used an in-slider crank, a four-bar linkage system that converted the rotational motion of the bar to linear motion (see Figure 1). The computer-controlled motor spins the crank arm in a single direction of motion at the required cycles per minute (rpm) and moves the carriage along the linear rail for a given displacement. The computer controller regulates the frequency of the system. The displacement of the carriage is proportional to the vertical oscillation (VO), and ground contact time (GCT) to simulate the runner's motion. Each of these components is required to move the radar device at the designated rpm, VO, and GCT.

The machine is powered by a Raspberry Pi was using Python 3. The Raspberry Pi P400 with a Python development environment was chosen due to: ease of use, simplicity of the syntax, large development community support with a diversity of pre-coded libraries, extendibility of the software platform, and commercial off the shelf (COTS) availability of hardware and “add-ons”. The outline for the software design is included below (see Figure 2).

Figure 2

Flowchart for software development



The machine was built to osculate the Garmin Varia radar device at speeds greater than 195 rates per minute (rpm), with a vertical oscillation (VO) of 11.8 cm, and a ground contact (GCT) time of 308 milliseconds (ms). This data was published by Garmin (Garmin, n.d.a & Garmin, n.d.b). When testing I placed the machine 150 meters away from the object with flags at one meter increments from 130 to 150 meters. When the object was traveling towards the radar device the first place of detection was radioed, using two-way radios (walkie talkies), from the person at the location of the radar device (person one) to the person in the car (person two). Person two radioed where the object was detected and recorded by person one. The setup took place in a controlled environment to ensure the radar would detect the correct object. This would limit the amount of ghost objects, stationary objects accidentally being detected as moving targets, as there is only one object moving at fast enough speeds.

Over the course of one week, I performed 25 tests with rpm, VO, and ground contact time (GCT), to mimic the motion of five different experimental groups of runners based on five color groups from Garmin data. Garmin published this data taken from different running applications, such as watches and other devices, for the public to view. Each of the five groups has a different rpm, VO and GCT, but these variables act as one variable as they change for each group. The purple group (5% of runners) has the smallest VO at 5.5 cm and shortest GCT at 208 milliseconds (ms) with the fastest cadence value at 195 rpm. The blue group contains a larger percentage of runners at 25%, with a slightly greater VO at 6.7 cm and the GCT of 218 ms, and a slower rpm at 185. The green group contains the highest percentage of individuals at 39%, the VO is substantially increased at 8.4 cm and a GCT of 241 ms, the rpm decreased at a similar rate

to the purple and blue group to 173 rpm. The orange group is similar in size to the blue group 24%, the VO increase is proportionally similar to the increase between the blue and green groups at 10.1 cm, the GCT and rpm are similar to the average increase at 278 ms and 162 rpm. The final group is the red group, similar to the purple groups containing 5% of runners, there is a proportional increase in VO to 11.8 cm, GCT to 308 ms (the longest interval of all the groups) and rpm at 151 rpm. This data was published by Garmin (Garmin, n.d.a & Garmin, n.d.b).

In order to maintain the highest level of safety while building the testing cage I wore safety glasses to cut and drill materials. I used a yellow reflective vest to ensure visibility to moving objects during data collection. I also wore safety glasses during testing and was a safe distance away from the testing apparatus as components could become detached while in motion. I ensured the testing area was clear of people before testing took place. I wore closed toe shoes at all times to protect myself from falling objects.

My data included measurements in meters where the object was detected and after my data was recorded, I analyzed which groups had the maximum range resolution. I did a one-way ANOVA test because the rpm, GCT, and VO are changing together, correlated, so they are acting as one variable. The alpha value for this test is .05.

Results

The data showed that the independent variable: rpm, GCT, and VO variations, did not affect the dependent variable, detection ability at distances greater than 140 meters. I had a total of five groups of data: each with different rpm, GCT, and VO that change as one variable. Each testing group had 25 trials with a total of 125 trials. I graphed the averages of each group as a bar graph with error bars showing 95% accuracy (see Figure 3). Based on the graph, each group has 95% accuracy above the set value from Garmin, 140 meters. The purple group had the highest detection average, while the blue group had the lowest (see Table 1). The group with the highest standard deviation was the red group at 3.497 meters, with the lowest standard deviation in the purple group at 1.190 meters (see Table 1).

Figure 3

Error Bar Graph with all Five Groups

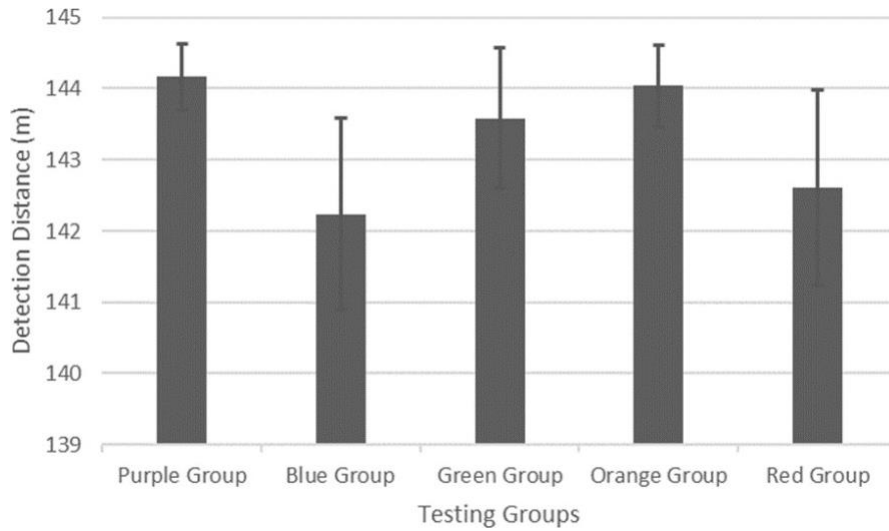


Table 1

Data Calculation Table

	Purple Group	Blue Group	Green Group	Orange Group	Red Group
Average	144.168	142.241	143.580	144.041	142.609
Standard Deviation	1.190	3.425	2.512	1.458	3.497
N Values	25.000	25.000	25.000	25.000	25.000
Standard Error	0.238	0.685	0.502	0.292	0.699
95% Confidence Rating	0.467	1.343	0.985	0.571	1.371

I used two one-way ANOVA tests to determine the significance between the two controls and the five different groups. I used an alpha value of .05 and compared it to the p-value to determine significance. For each of the groups the p-value was below the alpha, the bottom dead center control's p-value was .014 and the Garmin set value 2.7E-09 (see Tables 2 and 3). Due to the significance, I ran post-hoc Tukey tests for each ANOVA to determine where the significance was located. I ordered the averages from least to greatest on each axis and calculated the minimum difference (D min value) needed for statistical significance. Each of the differences

was greater than the minimum difference, finding significance for each data pair and, most importantly, the two controls (see Tables 3 and 5).

Table 2

ANOVA Results with Bottom Dead Center Control

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	111.577	6.000	18.596	2.793	.014	2.173
Within Groups	819.000	123.000	6.659			
Total	930.577	129.000				

Table 3

Tukey Test Results with Bottom Dead Center Control

	Bottom dead center	Blue Group	Red Group	Green Group	Orange Group	Purple Group
	720	3545	3560	3592.5	3597.5	3605
Bottom dead center	720 x	2825	2840	2872.5	2877.5	2885

D min Value: .931

Table 4

ANOVA Results with Garmin Control Value

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	321.833	5.000	64.367	11.422	2.7E-09	2.277
Within Groups	811.500	144.000	5.635			
Total	1133.333	149.000				

Table 5

Tukey Test Results with Garmin Control Value

	Garmin Set Value	Blue Group	Red Group	Green Group	Orange Group	Purple Group	
	3500	3545	3560	3592.5	3597.5	3605	
Garmin Set Value	3500	x	45	60	92.5	97.5	105

D min Value: 1.947

After running both Tukey tests and ANOVAs, I found significance, and rejected the null hypothesis; the radar device was able to detect all ranges of z-axis movement with greater than 95% accuracy. My research hypothesis was that the device can detect an oncoming object with greater than 95% accuracy with the five groups in different ranges of motion. The results from both ANOVA and Tukey tests supported this (see Tables 2 and 3).

Discussion and Conclusions

The purpose of my research was to investigate if detection by a 24 GHz radar device affected the detection of moving objects when moving in the z-axis. The five test groups were organized according to a combination of three characteristics: vertical oscillations, ground contact time, and rate per minute (cadence). Vertical oscillation is how much the person bounces, ground contact time is how long the runner's foot stays on the ground, and rate or steps per minute is how many steps are being taken. After 25 trials from each group, they were compared to each of the controls, the control set by Garmin on the device and the control found when testing the 24 GHz device. The results from this experiment suggest there is little evidence to support that movement in the z-axis lowers the detection distance to less than 140 meters. When compared to the Garmin control, the p-value was 2.7E-09 and compared to the found control, the p-value was .014. These values are below the designated alpha of .05, meaning the detection distance was above 140 meters over 95% of all trial runs. I followed up the ANOVA test with a Tukey Test to locate where significance was located between the controls and test groups. When comparing the Dmin value to the difference between the two groups, the Dmin value was lower than the difference suggesting that significance had been found. This was the case for all five testing groups.

With this research, the conclusion is that a radar device mounted to a pedestrian would have a detection ability high enough for adequate detection. The 24 GHz radar device moving in

the z-axis would have similar results to one with no movement making this product usable. No other similar research has been done with radar detection in the z-axis; this research was compared to a “Radar system for bicycle -a new measure for safety”. In this study, Englund, C., et al. (2019) concluded that the rate of peddling affected the detection ability as there was more movement in all directions. With pedestrians moving in all axes (x, y, and z), radar detecting capabilities may be drastically decreased, making a product not worthwhile. Movement in the z-axis was determined to not have an effect in distinguishing objects with increased movement, contrary to a study done by Hägelen (2019). This study did not mention which axis of movement caused the problem, therefore the conclusion that z-axis movement causes the problem cannot be made. The radar device could be moved out of aperture view, making it impossible to detect objects. However, this product’s real-world application signifies that radar detection is accurate when oscillating in the z-axis.

This research determined that z-axis movement does not result in decreased detection capabilities of the 24 GHz radar device. I hypothesized that with the five groups in different ranges of motion, the device would be able to detect an oncoming object with greater than 95% accuracy. There were no outliers in the 125 trials.

There are two key areas that should be considered in future research before a 24GHz radar detection device is designed for pedestrians. The first is to conduct similar testing in other axes (x and y) to determine if other types of simulation movement limits detection distance. Along with independent research on other axes, having a 24 GHz radar device simulate movement in all three axes simultaneously will best determine if the radar detection ability is useful for pedestrians. The second area is to research the health effect of near-field radio frequency radiation of 24 GHz radar devices. Balzano (1995) published that the human body absorbs 95% of energy in the first millimeter leading to burns. This device would be in close proximity to the skin, which may cause damage to the user. My research did not focus on this area; future testing is necessary to determine if this would be an issue. Overall, this is the first step towards a radar device for pedestrian usage as z-axis movement does not substantially affect detection ability.

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**Food for Thought: Can Intermittent Fasting Induced Ketosis Ameliorate Dementia by
Decreasing Tau Hyperphosphorylation and Neuroinflammation in *Drosophila
melanogaster*?**

ABSTRACT

Background: Dementia is highly prevalent neuropsychiatric condition characterized by impairments in memory, reasoning, mood, and behavior. Yet it has no effective treatment that targets the underlying biochemical pathology. The main goals of this project were to utilize a *Drosophila melanogaster* model of Dementia and determine whether ketosis induced by intermittent time-restricted feeding (iTRF) can lead to decreased mortality, improved memory, and enhanced locomotor function. **Methods:** flies with the V337M Tau mutation were used as a validated model of dementia. Both demented and control flies were subjected to either: (a) 24 hours access to food/ad libitum or ad lib OR (b) a Time Restricted Feeding (TRF) schedule with 10 hours of fasting during lights off and 14 hours of access to food, mostly during lights on. To assess the effect on lifespan, the percent of flies surviving over time, within each group, was calculated. Impaired geotaxis, diminished climbing motivation and ability, was assessed as a measure of locomotor ability. The Aversive phototaxis suppression assay was used to assess learning/memory; flies learned to avoid light that is paired with an aversive stimulus. Group differences were analyzed with survival curves. Chi-square tests were used for the categorical variables. **Results:** Survival curve analysis showed that the flies subjected to iTRF for 4 days lived longer than flies who fed ad lib, with the effect being more pronounced among the dementia group. Flies with Dementia had impaired climbing ability compared with controls, but within each group, there was no significant difference in locomotor function, among those fed ad lib versus iTRF. Flies with dementia demonstrated significant impairment in short-term memory and learning compared to the control flies (p-value = 0.03). iTRF did not improve short-term memory among control flies (p-value = 0.55) but greatly enhanced memory and learning in the dementia group (p-value = 0.04). **Conclusion:** Intermittent Time Restricted Feeding, and associated ketosis, may be a promising new intervention for dementia. Future studies should evaluate the underlying metabolic pathways as well as the changes in brain pathology that accompany improvement in clinical symptoms.

INTRODUCTION

Dementia is a devastating neuropsychiatric condition characterized by impairments in memory, reasoning, mood, and behavior; the decline in mental status is typically significant enough to preclude daily independent functioning (Gale, Acar, Daffner., 2018). The most common forms of dementia are seen in Alzheimer's disease (AD) for adults over age 65, and frontotemporal dementia (FTD) among individuals younger than 65 years (Rathnavalli, 2002). Based on World Health Organization estimates, more than 55.2 million people worldwide currently suffer from dementia, with approximately 7 million new cases per year, and an anticipated increase to 139 million in 2050 (Dementia, 2021). Despite the prevalence and impact of dementia, it has no effective treatment besides some drugs that can delay symptom progression. No treatment strategy targets the underlying biochemical pathology (Poudel and Park, 2022).

On a cellular level, neuronal communication in dementias is affected by two main culprits – tau and amyloid proteins. In healthy neurons, tau is found within the axons where it binds to microtubules, stabilizing them and maintaining normal neuronal architecture. A high degree of phosphorylation results in tau detachment from microtubules and subsequent tau aggregation, finally causing the formation of neurofibrillary tangles (Iqbal et al., 2010). Amyloid which starts out as amyloid precursor protein can be processed to produce either a healthy soluble protein or one that is toxic (amyloid-beta or A β) which clumps and accumulates into amyloid plaques. Together, extracellular amyloid plaques and intracellular neurofibrillary tangles, represent the classic neuropathological hallmarks of AD. Finally, oxidative stress, mitochondrial dysfunction, and neuroinflammation all have an additive effect in contributing to the ultimate disease presentation of AD (Pugazhenti et al., 2016).

Recent research suggests that in AD and FTD, beta amyloid clusters precede abnormal tau. Once amyloid-beta has accumulated to a certain level it leads to the production of more amyloid-beta and more abnormal tau and latter is associated with clinical symptoms (Jack et al., 2019). Also, reduction of Tau protein levels leads to an amelioration of A β -induced learning and memory impairment (Robertson et al., 2007). Tau pathology in various forms is also seen in a host of other neurodegenerative conditions characterized by dementia and movement disorders, including chronic traumatic encephalopathy or CTE (Zhang et al 2022). Given the key role it plays in most

dementias and its association with onset of clinical symptoms (figure 1), Tau is an attractive target for prevention and therapy of such neurodegenerative disorders.

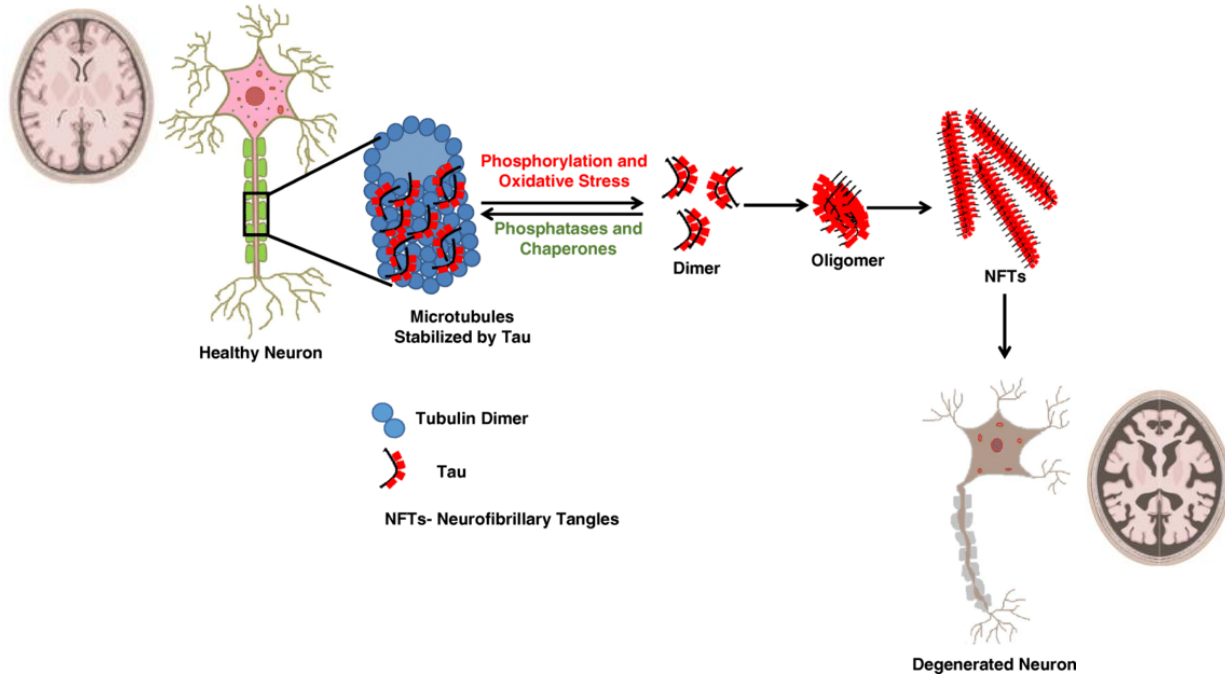


Figure 1. Tau Hyperphosphorylation pathway for neurodegeneration (modified from Nalini et al, 2018, Journal of Molecular Neuroscience)

While many new drugs for dementia are under investigation, none of the existing drugs works to prevent or modify the cerebral pathology of dementia. Also, effective drug delivery to the brain is hindered by the blood-brain-barrier, which is a network of closely spaced cells and blood vessels which prevent most substances from reaching the brain (Daneman and Pratt, 2015). Nutrition has been proposed a key modifiable factor in the progression of dementia and many pathophysiologic mechanisms connect glucose metabolism to Alzheimer’s disease, where hyperglycemia is associated with neuroinflammation oxidative stress which can trigger the amyloid cascade of AD (Taylor et.al. 2017). Thus, the ketogenic diet and ketone body supplementation have been proposed as potential therapeutic options for Alzheimer’s disease. The ketogenic diet is a high saturated fat/low carbohydrate diet switches the body from glucose metabolism to fat burning and producing ketone bodies as an alternative fuel to glucose (Dowis and Banga, 2021). Ketosis can be achieved through either fasting or carbohydrate restriction and ketone bodies have been shown to have beneficial effects on neurons by decreasing hyperexcitability and inflammation (Hertz et al., 2015). Recent studies have indicated that

intermittent fasting, which is less restrictive than ketogenic diets, may protect against neurodegeneration observed in animal models of Parkinson's disease, Huntington's disease, and traumatic brain injury (TBI) following dietary intermittent protocols but little is known of the outcome in Alzheimer's and Frontotemporal dementia (Nasiruddin et al., 2020).

Drosophila melanogaster or the common fruit fly is a convenient and efficient model of neurodegenerative disease and flies have been used successfully to dissect the genetic basis of complex behaviors such as sleep, learning, and memory (Lessing and Bonini, 2009). Previous studies have clearly shown that the expression of dementia-related gene products (tau protein and A β 42 peptide, respectively) causes expected phenotypes in flies (Bonner and Boulianne, 2011). Like AD patients, flies show a predictable decline of neurons upon A β 42 and/or Tau overexpression and the associated deficits in cognition and behavior can be analyzed using validated assays (Prubing, Voigt, and Shulz, 2013).

Main Objectives

To use a *Drosophila melanogaster* model of dementia and determine whether ketosis induced by intermittent fasting or time-restricted feeding (TRF) can lead to:

1. Decreased mortality or a measurable positive impact on lifespan.
2. Improved locomotor function measure by the negative geotaxis assay
3. Enhanced cognitive function demonstrated by improved learning in the aversive conditioning task.

Methods and Study Design

Fly Stocks were obtained from Bloomington Stock Center (Bloomington, Indiana) and raised at 23° C on standard cornmeal-molasses medium. Flies for the experimental group (w[1118]; P{w[+mC]=GMR-MAPT.V337M}10/TM3, Sb[1]) – expressed human microtubule-associated protein tau (MAPT) with amino acid change V337M and the control group (w[1118]) did not contain abnormal tau.

Mutations in the microtubule-associated protein tau (MAPT) gene, in humans, causes deposition of hyperphosphorylated tau protein in neurons and glia and are associated with inherited frontotemporal dementia (FTD) (Spillantini et al., 1998). The V337M MAPT mutation,

in particular, has been associated with FTD with severe frontotemporal and limbic degeneration and cognitive deficits (Sumi SM et al., 1992). Furthermore, the structure and composition of tau aggregates associated with this mutation are similar to those found in neurofibrillary tangles in Alzheimer disease (AD) (Spillantini et al., 1996). Thus, flies with the V337M MAPT mutation offer a robust model of tauopathy associated dementias, including Alzheimer’s Disease and Frontotemporal Dementia (Spina et al., 2017).

Intermittent fasting or time-restricted feeding is gaining popularity and scientific support as a means to attenuate aging related processing, in both flies (Gill et al., 2015) and humans (de Cabo R and Mattson MP, 2019) Recent research investigating various intermittent time-restricted feeding (iTRF) regimens (Ulgherait et al., 202) was used to derive an iTRF regimen for this study, taking into consideration the fact that flies with neurodegenerative disease may be more vulnerable to fasting states. A fasting window of 10 hours overnight (8 PM- 6 AM), for a period of 4 days was found to be optimal based on initial experiments.

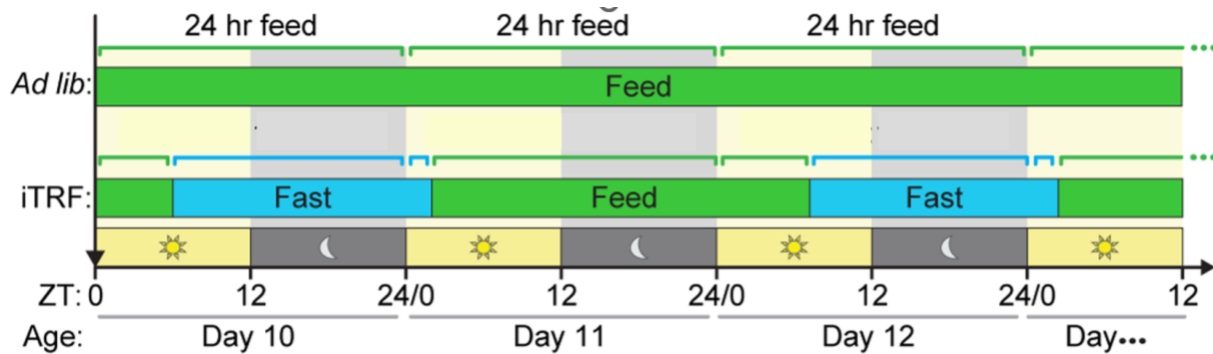


Figure 2: Feeding schedule for fly cohorts in the Ad lib and iTRF groups (modified from Ulgherait et al., 2021, Nature)

All flies were raised on *ad lib* conditions until day 10 post-eclosion upon which time flies were placed on various feeding regimes (Figure 2). For consistency, *ad lib* control flies were flipped on to fresh food at the same time as experimental diet flies were transferred to fasting media, and once again when fasting flies were flipped on to regular adult media.

Longevity: flies were placed in each of two vials, per condition (control ad lib, control iTRF, dementia ad lib, dementia iTRF). Flies were transferred to new vials every 3 days to avoid including their offspring in the longevity count. Flies were counted daily, and number of dead flies, number of living flies, and the percentage of surviving flies were recorded. Death was scored at time of flipping, and lifespan compared by log-rank analysis.

Negative Geotaxis or depression like state: Negative geotaxis is defined as the motion in response to the force of gravity (Neckameyer et al. 2016). Flies placed in a vial, were tapped to the bottom, and were given 10 seconds to demonstrate negative geotaxis by migrating upward to a line 2 inches below the vial lid. Number of flies above the demarcated line, at 10 seconds, was recorded (Figure 3). This assay measures both motivation as well as locomotor ability.

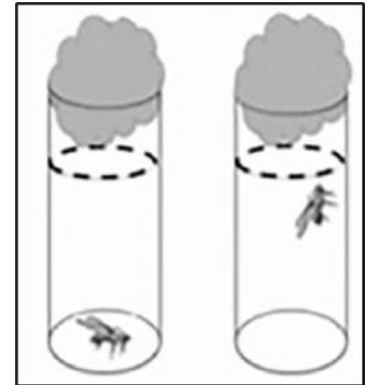


Figure 3: Geotaxis assay to assess lack of motivation and locomotor status.

Learning and Memory

Associative learning and intact memory help organisms, including insects, adapt to their environment which is essential for survival (Rescorla RA, 1988). Fly behavioral assays, involving Pavlovian conditioning tests of memory and learning, are well established (Iijima K 2004; Le Bourg & Buecher (2002). In this study, learned suppression of photopositive tendencies were evaluated in demented and control flies.

Phototaxis represents the fly's natural affinity to migrate towards light, but this innate tendency can be suppressed when flies are subjected to an aversive stimulus coupled with light

exposure (Le Bourg and Buecher). A choice chamber was created with one end of the chamber covered with opaque black material and the other end open to ambient light. When flies migrate to the lit chamber, they received a noxious stimulus delivered via a buzzing device causing them to leave the lit side. The process is repeated during a 1 minute interval for a total of 5 times and after that the number of flies in the darkened versus light chambers is documented. The proportion flies found in the dark chamber (i.e. the ones who “learned” to avoid potential danger) was defined as the learning index.

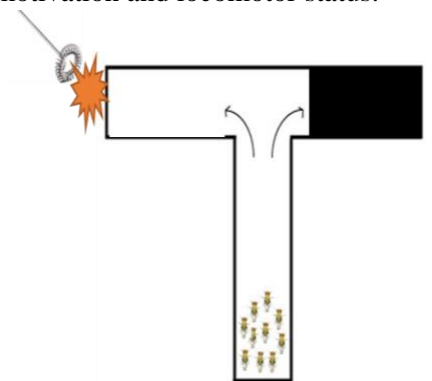


Figure 4: Light-Dark Choice Chamber, where light is coupled with an aversive stimulus.

RESULTS

Preliminary experimentation found that iTRF (14/10) for 4 days was best tolerated by flies with dementia, although control flies could go longer on this fasting regimen.

Longevity: survival curves were plotted using a Kaplan Meir model (figure 5) and showed that flies without dementia lived longer than demented flies, regardless of which feeding schedule they were subjected to. Within the control and dementia cohorts, the flies subjected to iTRF for 4 days lived longer than flies who fed ad lib, with the effect being more pronounced among the dementia group.

Geotaxis assay: as shown in table 1 and figure 6, Flies with Dementia had impaired climbing ability compared with controls, but within each group, there was no significant difference in locomotor function,

among those fed ad lib versus iTRF.

Table 1: Proportion of flies with impaired geotaxis/depression like state, by group

Fly Cohort	n/Total (%)	Odds Ratio: Impaired Geotaxis, TRF vs. ad lib (95% CI)	P Value
CND	3/16 (18.8)	1.0	n/a
CTRF	3/19 (15.8)	1.23 (0.21-7.15)	0.582
Fly Cohort	n/Total (%)	Odds Ratio: Impaired Geotaxis, Dementia TRF vs. ad lib (95% CI)	P Value
DND	8/24 (33.3)	1.0	n/a
DTRF	4/12 (33.3)	1.0 (0.23 – 4.35)	0.64

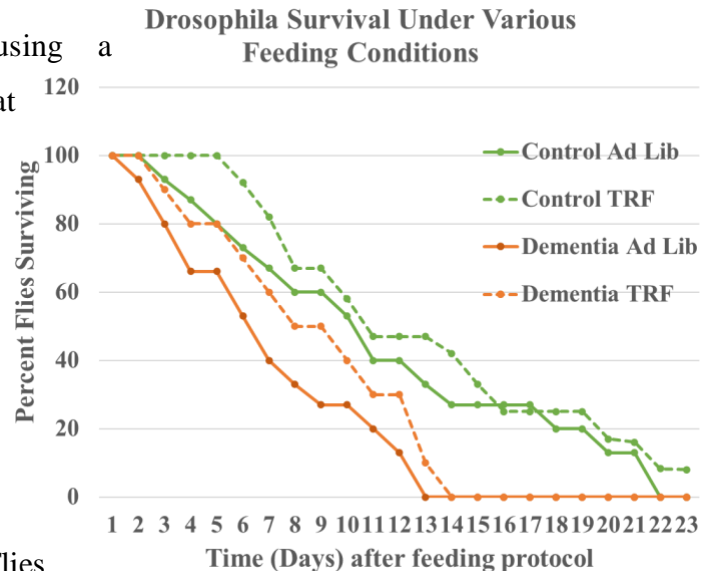


Figure 5: Percent Flies surviving over time

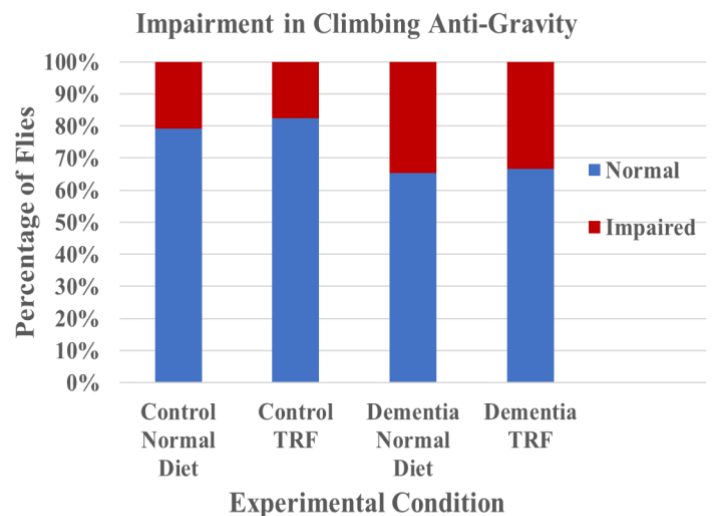
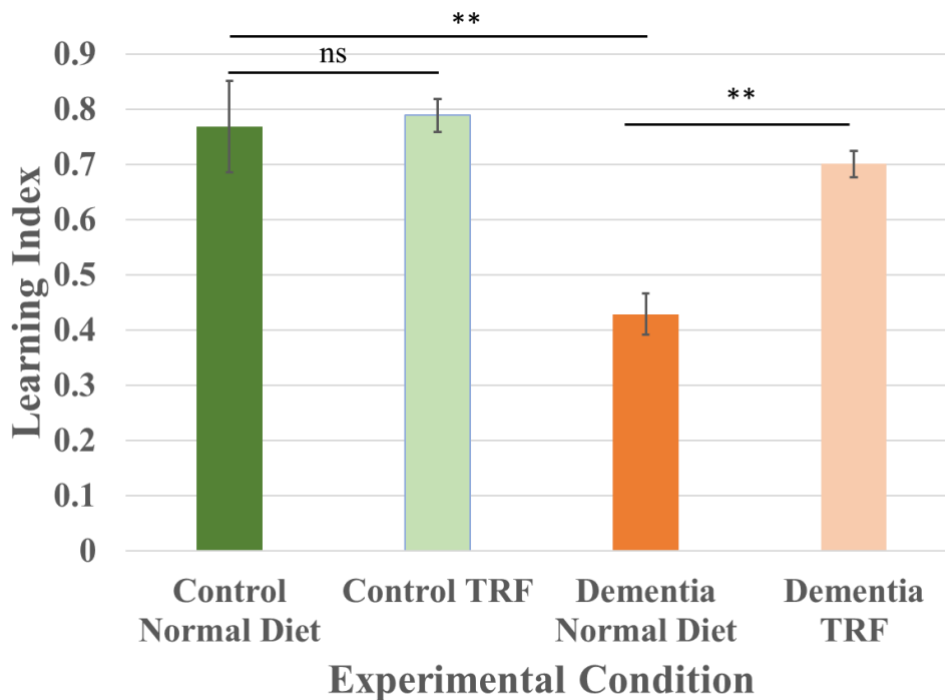


Figure 6: Indicated above is the percentage of flies with impaired geotaxis for the various groups.

Demented flies had 33% impairment in climbing compared to only 19 percent among controls. However, within the controls there was no difference between the ad lib and iTRF group (p-value = 0.582) and there was no difference between the two diet s for the demented group either (p=value = 0.64).

Learning and Memory: After receiving an aversive stimulus, the number of flies who “learned” to avoid light were recorded over 3 trials. Learning index was defined as the percentage of flies that successfully suppressed phototaxis (or the innate desire to migrate towards light) and migrated to the unlit side of the chamber. As shown in figure 7, flies with dementia demonstrated significant impairment in short-term memory and learning compared to the control flies (p-value = 0.03). Notably, iTRF did not improve short-term memory among control flies (p-value = 0.55) but greatly enhanced memory and learning in the dementia group (p-value = 0.04).



ns – not significant ** - p-value <0.05

Figure 7: Short-term Memory Evaluation by Aversive Phototaxis Suppression Assay. Learning Index calculated based on percentage of flies who “learned” to avoid light

DISCUSSION and CONCLUSIONS

The purpose of this study was to utilize *Drosophila melanogaster* as a model organism and study whether metabolic manipulation using time restricted feeding could improve mortality, locomotion, and memory among demented and control flies. Flies with the V337 MAP Tau mutation demonstrated impairments consistent with dementia as previously described (Spina et al., 2017) – they have shorter life spans, impaired climbing and motivation, and deficits in learning and memory, when compared with control flies. Intermittent time restricted feeding or iTRF enhanced lifespans of both control and demented flies but did not improve locomotor abilities in either group. Flies with dementia, but not the controls, showed improved learning and memory after iTRF.

iTRF and Mortality

The results of this study are consistent with prior literature showing dementia is a reliable predictor of human mortality (Rizzuto et al., 2012). Caloric restriction via intermittent fasting in humans (Dowis and Banga, 2021) and time restricted feeding in flies (Ulgherait et al., 2021) can prolong lifespan. In this project, iTRF decreased mortality among flies with dementia and showed that although they may be more physically vulnerable, they can also benefit from ketosis.

iTRF and Climbing Behavior

While demented flies had impaired climbing compared with control flies, iTRF did not improve locomotion in either group. Negative geotaxis in flies is the innate motivation to climb vertically when startled; impairment in this response has been observed in flies with lower serotonin and octopamine levels (Meichtry et al., 2020), which are associated with depression in flies. Intact geotaxis also requires good locomotor ability and negative geotaxis has been shown to be impaired among flies with neurodegenerative processes such as Alzheimer and Parkinson disease, as well as flies with brain injury or Chronic Traumatic Encephalopathy (Lateef et al., 2019). The neurodegeneration brought on by hyperphosphorylated tau causes parkinsonism, in addition to dementia, which may explain why iTRF was not successful in overcoming these deficits in this model of dementia.

iTRF and Memory

Flies with dementia, but not the controls, showed improved learning and memory after iTRF possibly because it is easier to discern enhanced cognition among flies who are significantly impaired to begin with. The three ketone bodies produced during fasting are acetoacetate, β -hydroxybutyrate and acetone and they are the major energy source (75%) for the brain. The proposed neuroprotective effects of ketone bodies include decreasing oxidative stress, neuroinflammation, mitochondrial impairment, hypometabolism and BBB disruption (Lorenzo, 2018). Especially relevant to the model of dementia used in this study, impaired glucose metabolism leads to a decrease in tau-O-GlyNAcylation that causes more hyperphosphorylation of tau (Lorenzo, 2018). By switching the fly metabolism to ketosis, it is possible that hyperphosphorylation of tau was diminished leading to less neuropathology and this improved cognitive function.

Findings from this study have tremendous implications for the treatment of dementia, a highly prevalent and devastating neurologic diagnosis. Intermittent fasting is a non-pharmacologic intervention that can be easily prescribed and perhaps the exact feeding schedule can be adjusted to meet the needs of the individual patient. It is also less restrictive than the ketogenic diet which necessitates the almost complete elimination of carbohydrates and can lead of adverse effects such as liver and kidney disease and vitamin deficiencies (Batch et al., 2020).

This study was limited by space and budget considerations and more extensive replicates, with different feeding schedules were not possible. Additionally, due lack of access to specialized equipment, ketosis could not be biochemically assessed in the flies.

iTRF may be a promising new intervention for dementia. Future studies should evaluate the associated metabolic pathways, as well as the changes in brain pathology, that accompany improvement in clinical symptoms, both in flies and in larger mammalian models. Ultimately such non-pharmacologic interventions may transform how we treat a variety of human neurodegenerative diseases.

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ABSTRACT

Rheumatoid arthritis (RA) is an autoimmune joint disease that affects nearly 1% of people worldwide. RA disproportionately affects women, indigenous peoples, and those of lower socioeconomic status, and it results in an estimated \$70 billion annual medical and economic burden. Tissue damage and destruction in this chronic, inflammatory condition results from interactions between immune cells and synovial fibroblasts. There is no FDA-approved therapy for preventing RA, which causes disability, reduced quality of life, and increased mortality. I performed an unbiased global scan of all 4,302 FDA-approved drugs and identified a significant association between reduced development of RA and the use of haloperidol (Haldol), which is used to treat certain mental disorders. I validated this link by analyzing 3 diverse nationwide health insurance databases of over 200 million people using Cox proportional hazards regression and Kaplan Meier survival analyses as well as random effects meta-analysis. I identified a dramatic and significant reduction in the risk of developing RA among people with mental disorders who were treated with Haldol compared to those treated with other anti-psychotics. Mechanistic studies revealed that Haldol also inhibited two important inflammatory cytokines – interleukins IL-1 β and IL-6 – in human macrophages and human synovial fibroblasts, two critical cell types in the development of RA pathology. Furthermore, Haldol inhibited inflammasome activation, as measured by ASC speck formation and caspase-1 cleavage, in human macrophages. Collectively, these studies identify Haldol as a potential drug repurposing candidate that could become the first preventive therapy for a major unmet medical need that causes disability in millions of people in the United States and across the world.

INTRODUCTION

Rheumatoid arthritis (RA) is a chronic autoimmune disorder that inflammatory disorder affecting tens of millions worldwide (Alamanos, 2006). RA is characterized by synovial inflammation and destruction of the bone and cartilage in multiple joints. The resulting joint damage can lead to disability and is even associated with premature death. RA disproportionately affects women; roughly 70% of those affected are women, as is the case with many autoimmune disorders (Alamanos, 2006). RA is associated with increased disability, reduced economic productivity, and increased mortality (Birnbbaum, 2010; Simons, 2012; Gunnarsson, 2015).

Although several drugs are approved for the management of RA, most have significant potential side effects. However, to date no medications have been approved for reducing the risk of RA or preventing the disease. Therefore, I sought to identify such a potential drug by analyzing health insurance databases to identify existing FDA-approved drugs that are associated with a reduced risk of developing RA. By using the power of these very large patient databases, I sought to enable the repurposing of an existing drug for a new disease indication (Boguski, 2009).

In this study, I examined whether exposure to haloperidol (Haldol), an FDA-approved drug for the treatment of schizophrenia or Tourette's disorder, affects the risk of developing RA. I also studied whether Haldol inhibits activation of the inflammasome, a complex of innate immune proteins (Latz, 2010) that play a critical role in RA (Mathews, 2014). I found that Haldol is associated with reduced development of RA and that Haldol inhibits inflammasome activation in cell models relevant to RA. These data suggest the possibility of repurposing this approved drug for treating or preventing RA.

METHODS AND MATERIALS

Health Insurance Claims Databases Analyses

Health insurance database information contains de-identified data that are Health Insurance Portability and Accountability Act (HIPAA)-compliant and were deemed by the University of Virginia Institutional Review Board (IRB) as exempt from IRB approval requirements.

Data Source

The retrospective study used claims data from the 1) PearlDiver Mariner database, which contains data on health care claims and medication usage for persons in provider networks over the time period 2010 to 2021; 2) Truven MarketScan Commercial Claims Database (IBM), containing health care claims and medication usage from the commercial insurance claims from employer-based health insurance beneficiaries from 2006 to 2020; 3) Veterans Administration Health database, which contains data on veterans over the time period 2001 to 2021.

Sample Selection

Patients were included in the analysis if they had continuous enrollment in the plan for at least 1 year, were at least 18 years of age at baseline, and were confirmed to have schizophrenia or Tourette's disorder (diagnosed on at least 2 separate occasions). Individuals with pre-existing RA prior to diagnosis of schizophrenia or Tourette's disorder were excluded. Disease claims were identified by International Classification of Diseases (ICD)-9-CM and ICD-10-CM codes. The General Population included patients with continuous enrollment for ≥ 1 year and who filled ≥ 1 pharmacy prescriptions for any medication.

Independent Variable

Exposure to Haldol or other anti-psychotics – the independent variable – was determined by whether patients filled pharmacy prescriptions for generic or brand versions, as identified by National Drug Codes.

Dependent Variable

Time from diagnosis of Schizophrenia or Tourette's to initial diagnosis of Rheumatoid Arthritis was the dependent variable.

Analyses

Analyses were performed with the use of R software, version 4.2.2 (the R project). To analyze the risk of RA between Haldol users and Haldol non-users (those who used other anti-psychotics), an adjusted Cox proportional hazards regression analysis was performed, and the Hazard Ratio was analyzed. The adjusted model included confounding variables that influence RA risk: Age, Sex, Smoking, Body Mass Index, and Charlson Comorbidity Index, and Year of plan entry. The Haldol Yes and Haldol No groups were also matched for these variables using greedy nearest neighbor propensity score matching using the R package MatchIt. Cox models were analyzed by chi square test. Kaplan-Meier survival plots were analyzed by log rank test. Patients were censored when they developed Rheumatoid Arthritis, left the plan, died, or switched to the other class of anti-psychotic. Statistical tests were 2-sided. P values < 0.05 were considered statistically significant.

Meta-analysis

An inverse-variance weighted meta-analysis was performed to estimate the combined hazard ratio (HR) and 95% confidence intervals (CI) using a random-effects model using the R package metafor. A prediction interval (PI) was computed using the predict function in metafor. A forest plot was created to depict the HR and 95% CI of each study, of the pooled results, and of the 95% PI.

Cell culture studies

All cell culture experiments were compliant with University of Virginia Institutional Biosafety Committee regulations. Human THP-1 macrophages were cultured in RPMI-1640 media (ThermoFisher) supplemented with 10% fetal bovine serum (FBS) and 1% penicillin–streptomycin. Human fibroblasts (Cell Applications) were cultured in HFLS medium (Cell Applications). Cells were maintained at 37 °C in a 5% CO₂ environment.

ASC speck imaging

THP-1 cells were seeded on chambered coverslips (30,000 cells/well) for 12 h were pretreated with Haldol (1 μM, Sigma-Aldrich) or 0.1% DMSO (control) for 2 h. Cells were treated with LPS (125 ng/mL) for 4 h and ATP (5 mM) for 15 min. Coverslips were fixed with 2% PFA (15 min at room temperature), washed with PBS, permeabilized, blocked with blocking buffer (PBS, 0.1% TX-100, 5% normal rabbit serum; 1 h at 4 °C), incubated with rabbit anti-human ASC antibody (AdipoGen, 1:200) with blocking buffer, and visualized with goat anti-rabbit-488 (ThermoFisher, 1:500). DAPI-stained slides were mounted using Fluoromount-G (Southern Biotech) and imaged by confocal microscopy (Nikon A1R). The number of ASC specks per 0.09 mm² field was quantified. Means were compared using two-tailed Student t test.

Caspase-1 western blotting

THP-1 cells were treated with LPS and ATP and pre-treated with Haldol (0.1–1 μM) for 1 h. Proteins from the cell-free supernatant were precipitated by adding sodium deoxycholate (0.15% final), followed by adding TCA (7.2% final) and incubating on ice overnight. Samples were spun down at 12000g for 30 min and pellets were washed 2 times with ice-cold acetone. Precipitated proteins solubilized in 4X LDS Buffer with 2-mercaptoethanol were resolved by SDS-PAGE on

Novex® Tris-Glycine Gels (Invitrogen) and transferred onto low fluorescence PVDF membranes (Biorad). The transferred membranes were blocked with LI-COR block for 1 h at room temperature and then incubated with anti-human caspase-1 antibody (AdipoGen, 1:1000) at 4 °C overnight. The immunoreactive bands were visualized using species-specific secondary antibodies conjugated with IRDye®. Blot images were captured using an Odyssey® imaging system.

IL-1 β and IL-6 Enzyme Linked Immuno-Sorbent Assay

THP-1 cells and fibroblasts were treated with LPS and ATP and treated with Haldol (0.01–100 μ M) as above. Secreted IL- β and IL-6 in the conditioned cell culture media were detected using ELISA kits (R&D Systems) according to the manufacturer's instructions. Means were compared using two-tailed Student t test.

RESULTS

I studied three health insurance databases: PearlDiver Mariner (151 million people from 2010 to 2021), Truven MarketScan Commercial Claims (158 million people from 2006 to 2020), and Veterans Administration (VA) Health database (11 million people from 2001 to 2021).

First, I performed an unbiased global drug scan of all 4,302 FDA-approved drugs to identify candidate drugs that might reduce the risk of developing RA. Because this procedure was computationally intensive, I used the VA database, the smallest of the three databases. In addition, because the VA database contained 20 years of data, the longest duration among the three databases, it was also more likely to yield a robust longitudinal finding.

I ran a Cox proportional hazards regression analysis for all 4,302 drugs to obtain their hazard ratio (HR), which is the risk of developing RA among drug users divided by the risk of developing RA among drug non-users. I used a cutoff of $HR < 0.8$, which is equivalent to a risk reduction of more than 20%, because that would be clinically meaningful. Further, I used a False Discovery Rate < 0.05 to correct for the multiple drug (4,302) comparisons. This global screen yielded haloperidol (Haldol), which is approved for the treatment of schizophrenia or Tourette's disorder, as the best drug candidate (**Figure 1**).

Drug	Hazard Ratio for Rheumatoid Arthritis	P (χ^2)
Haloperidol (Haldol)	0.782	0.0002

Figure 1. Unbiased Global Scan of 4,302 FDA-approved Drugs identifies Haloperidol (Haldol) as protective against development of Rheumatoid Arthritis in the Veterans Administration health database. P (χ^2 test) significant using overall False Discovery Rate < 0.05.

Haldol associated with reduced development of Rheumatoid Arthritis

I then evaluated this candidate drug, Haldol, in all three databases by comparing patients diagnosed with schizophrenia or Tourette’s disorder (the population at risk) on the basis of use of Haldol versus use of other anti-psychotic drugs. The prevalence of RA among Haldol users was significantly less than among Haldol non-users in this population and less than in the entire population (Figure 2).

Database	Entire Population	Schizophrenia / Tourette’s		Prevalence Reduction
		Haldol – NO	Haldol – YES	
PearlDiver Mariner 2010-2021	1.87% N ~ 151 million	2.02%	1.41% *	30%
Truven MarketScan 2006-2020	1.90% N ~ 158 million	1.98%	0.88% *	56%
Veterans Administration 2001-2021	1.27% N ~ 11 million	1.26%	0.42% *	67%

Figure 2. Prevalence of Rheumatoid Arthritis is lower in Haldol users (Haldol-YES) compared to Haldol non-users (Haldol-NO) in patients with Schizophrenia or Tourette’s disorder and compared to the entire population, in the PearlDiver Mariner, Truven MarketScan, and Veterans Administration health databases. * P < 0.001 (χ^2 test).

Next, I performed a retrospective, longitudinal cohort analysis using a Cox proportional hazards regression analyses to estimate the hazard of RA in relation to Haldol use. Patients in these databases were not randomly assigned to Haldol treatment; therefore, I performed propensity score matching, a causal inference approach (Rosenbaum & Rubin, 1983), to assemble cohorts

with similar baseline characteristics, thereby reducing possible bias in estimating treatment effects. Additionally, to control for any residual covariate imbalance, I adjusted for confounders associated with RA: age, sex, smoking, and body mass index, Charlson comorbidity index (a measure of overall health), and year of entry into the database. These adjusted Cox proportional hazards regression models in the propensity-score-matched populations also showed a protective association of Haldol use (**Figure 3**). In PearlDiver, Haldol exposure was associated with a 26% reduced hazard (adjusted hazard ratio (aHR), 0.744; 95% CI, 0.643 to 0.860; $P < 0.0001$). In Truven, Haldol exposure was associated with a 43% reduced hazard of developing RA (aHR, 0.567; 95% CI, 0.397 to 0.810; $P = 0.0009$). In the VA, Haldol exposure was associated with a 50% reduced hazard (aHR, 0.515; 95% CI, 0.272 to 0.978; $P = 0.021$).

Next, I estimated the combined hazard in the three databases based on an inverse-variance-weighted meta-analysis using a random-effects model (DerSimonian & Laird, 1986). The meta-analysis identified a protective effect of Haldol against incident RA (pooled adjusted hazard ratio = 0.661; 95% CI, 0.523, 0.836; $P=0.0006$) (**Figure 3**). The pooled hazard ratio (0.661) and confidence interval (0.523 to 0.836) inform us on the precision of the mean effect.

I also determined the prediction interval, which provides insights into the range of outcomes in a hypothetical future study (IntHout, 2016). The 95% prediction interval was 0.464 to 0.942 (**Figure 3**), implying a future clinical trial has a >95% probability of identifying a protective effect (hazard ratio < 1.0) of Haldol against RA.

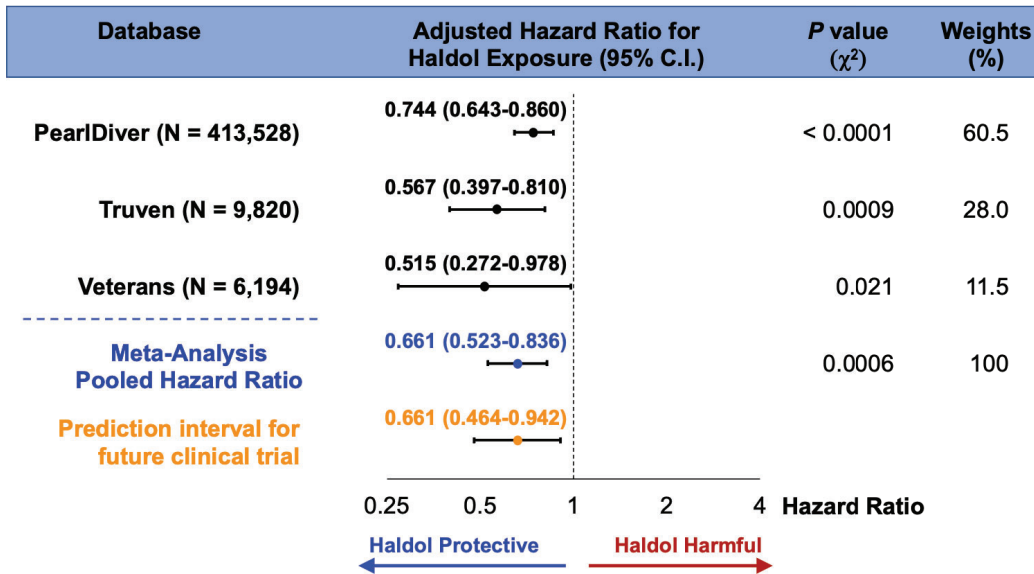


Figure 3. Forest Plot shows that risk of developing Rheumatoid Arthritis is reduced with Haldol exposure. Hazard ratios for developing Rheumatoid Arthritis derived from propensity score-matched models adjusted for the confounding variables listed in Methods and Materials were estimated separately for database. Adjusted hazard ratios along with their 95% confidence intervals are shown as black lines. The blue dot shows the pooled estimate of the adjusted hazard ratio and the 95% confidence intervals for meta-analyses using an inverse-variance-weighted random-effects model. The orange dot and black lines shows the prediction interval. The broken vertical line represents an adjusted hazard ratio of 1, which denotes equal risk between Haldol exposure and non-exposure. Horizontal bars denote 95% confidence intervals (CI). P values (χ^2 test) and weights assigned to each database per the random-effects model are reported.

Next, I performed Kaplan-Meier survival analyses to estimate the probability of developing RA over time. Haldol use was associated with a significantly slower rate of developing RA in the PearlDiver, Truven, and VA databases (**Figure 4**).

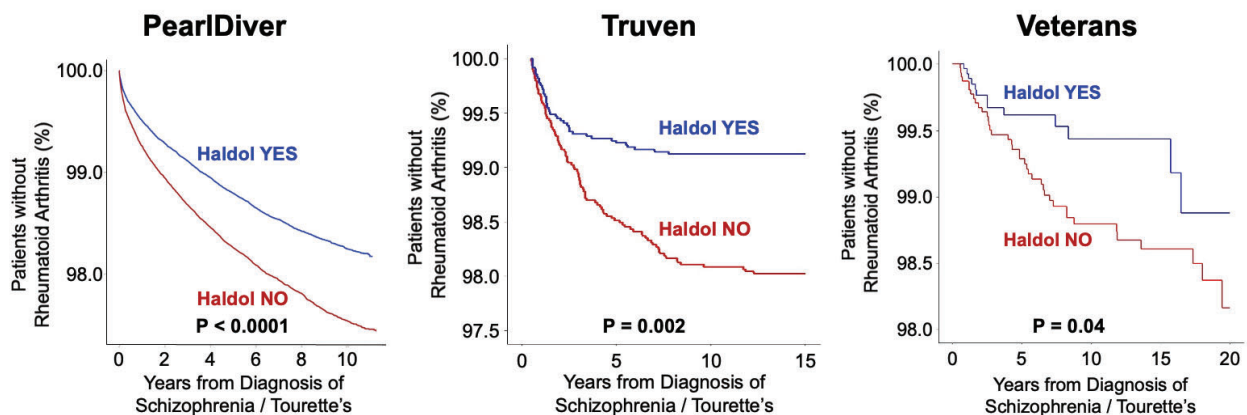


Figure 4. Kaplan Meier survival plots show Rheumatoid Arthritis developed at a slower rate over time in Haldol users (Haldol YES) compared to Haldol non-users (Haldol NO) in the PearlDiver, Truven, and Veterans health databases. P values by log rank test.

Haldol inhibits inflammasome activation

Since Haldol use was associated with reduced risk of RA, I sought to understand the mechanisms by which Haldol could confer protection against RA. Inflammasome activation is considered a key driver of RA since patients with RA exhibit high levels of the inflammasome constituents NLRP3, ASC, and Caspase-1 (Mathews, 2014). In addition, lipopolysaccharide (LPS) and adenosine triphosphate (ATP), which activate the inflammasome (Mariathasan, 2004), are also elevated in patients with RA (Arabski, 2012; Parantainen, 2022 ; Tripathy, 2021). Therefore, I tested whether Haldol could inhibit inflammasome assembly by monitoring ASC speck formation (Masumoto, 1999) in human THP-1 macrophages using immunofluorescence. Haldol inhibited LPS and ATP-induced ASC speck formation (**Figure 5**) ($P = 0.007$), indicating that Haldol blocked inflammasome assembly.

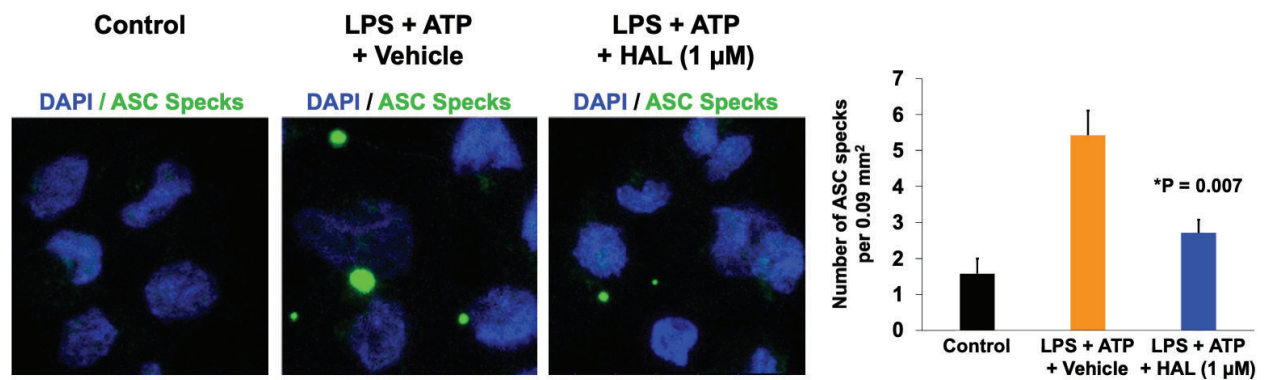


Figure 5. Representative immunofluorescent images show LPS+ATP induces ASC specks (green circular aggregates) in human THP-1 cells, and Haldol (HAL) reduces specks. Cell nuclei stained blue by DAPI. Bar graph of mean and SEM. $N = 7$ per group. $*P=0.007$ (LPS+ATP+HAL compared to LPS+ATP+Vehicle), two-tailed Student t test.

Next, I monitored inflammasome activation by assessing cleavage of inactive pro-caspase-1 into active caspase-1 (Mariathasan, 2004) in macrophages, using western blotting. Haldol robustly inhibited LPS and ATP-induced caspase-1 cleavage, confirming that Haldol inhibits inflammasome activation (**Figure 6**).

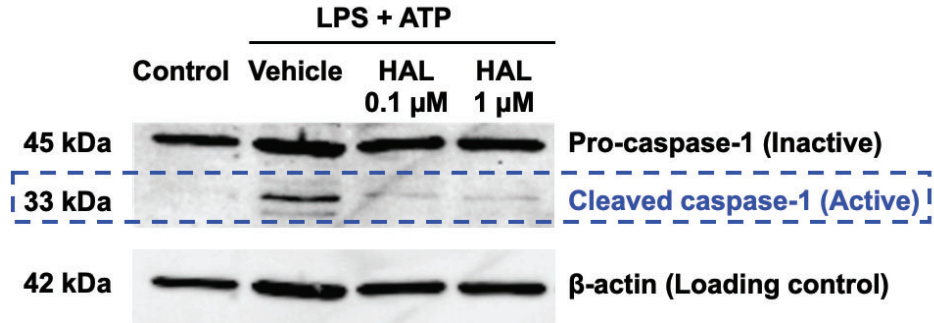


Figure 6. Representative western blot images show LPS+ATP induces cleavage of pro-caspase-1 (45 kDa) into active caspase-1 (33 kDa) in human THP-1 macrophages, and Haldol (HAL) reduces caspase-1 activation induced by LPS+ATP. β -actin loading control shows protein loading per lane. N = 3 per group.

Finally, I used ELISA to quantify levels of interleukin (IL)-1 β , a cardinal inflammasome output, and IL-6, which lies mechanistically downstream of IL-1 β , both of which are elevated in RA patients (Komatsu N & Takayanagi, 2022). In RA, the principal cellular source of IL-1 β is macrophages and that of IL-6 is synovial (joint) fibroblasts (Zhang, 2019). I found that IL-1 β release in macrophages was robustly induced by LPS and ATP stimulation, and it was reduced by exposure to Haldol in a dose-dependent manner ($P < 0.05$) (**Figure 7**). The downstream impact of inflammasome activation was assessed in human synovial fibroblasts by measuring IL-6 secretion. IL-6 release was robustly induced by LPS and ATP stimulation, and it was reduced by Haldol in a dose-dependent manner (**Figure 7**). These data demonstrate that Haldol inhibits inflammasome activation and subsequent inflammatory pathways.

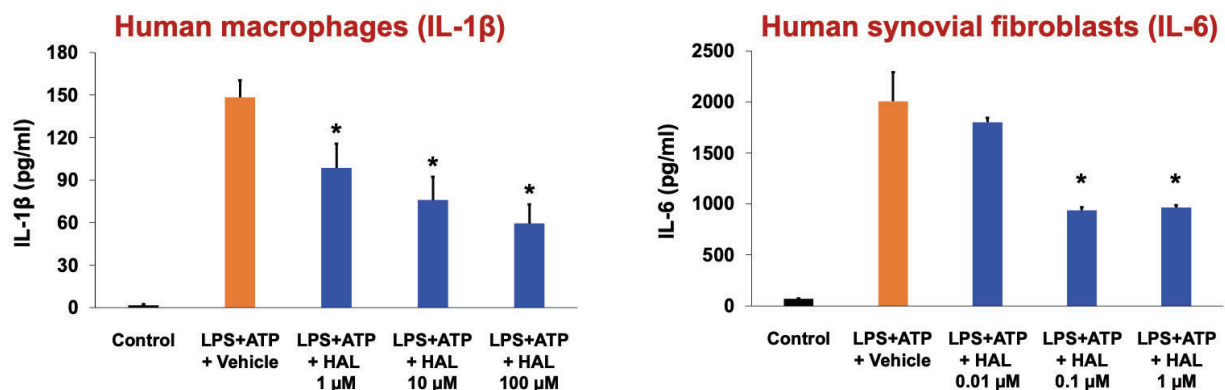


Figure 7. Representative ELISAs of secreted IL-1 β from human THP-1 macrophages (**left**) and IL-6 from human synovial fibroblasts (**right**), showing LPS+ATP induces secretion of these cytokines, and Haldol (HAL) reduces secretion induced by LPS+ATP. N = 3 per group. Data show mean and SEM. * $P < 0.05$ (LPS+ATP+HAL compared to LPS+ATP+Vehicle), two-tailed Student t test.

DISCUSSION AND CONCLUSIONS

I identified a strong and significant association between Haldol use and lower rates of RA. A strength of the insurance database analyses is the replication in three cohorts of hundreds of millions of people that comprise the majority of all U.S. adults. Another strength is adjustment for confounders and propensity score matching, which simulates randomization and increases the validity of my conclusion. Nevertheless, as this retrospective study was not randomized, there could be residual confounding or selection bias. I also present biochemical evidence that Haldol reduces inflammasome activation in cell culture systems. These investigations collectively suggest a potential beneficial effect of Haldol in forestalling RA onset. These studies also provide a rationale for performing randomized controlled trials of Haldol for RA, which can provide insights into causality. Demonstrating Haldol's benefit for RA in a such a prospective trial could benefit millions suffering from physical and emotional disability.

The tissue concentration of Haldol in schizophrenia patients is 10 μM (Kornhuber, 1999, Swathy & Banerjee, 2017). I found that much lower concentrations of Haldol (0.1–1 μM) reduced inflammasome activation. Therefore, doses of Haldol lower than currently prescribed for mental disorders might be beneficial for RA. As Haldol is a cell-permeable small molecule, another potential mode of delivery is a sustained release implant or transdermal patch. Alternatively, it could be directly injected into affected joints. Such strategies would limit potential side effects.

Despite numerous advances into the mechanisms of RA, there is still no approved preventive therapy. Traditional approaches to drug development consume more than a decade and nearly \$3 billion, with more than 99% of drug candidates failing (Dimasi, 2016). My identification of an unrecognized activity of an existing FDA-approved drug, coupled with demonstrating its efficacy in disease-relevant cell models, could hasten and reduce the cost of drug development of a novel therapy for RA. It would also be interesting to determine whether Haldol is beneficial in other inflammasome-driven diseases such as multiple sclerosis and macular degeneration.

DISCLOSURE: I am named as an inventor on two patent applications (US patent 63/483,029 and US patent 63/483,061) on using Haldol filed by the University of Virginia.

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Rina Kopylev
Washington-Liberty

Abstract

Throughout the last several millennia, candles have played a very significant role in human lives. Today, many different substances are used to produce wax, some of them producing soot that is harmful to human health. This experiment explored the properties of palm, paraffin, soy, and beeswax. This experiment investigated the effect of candle wax material on burn rate and soot production. It was hypothesized that different wax materials would have different burn rates and soot production, and that palm wax would have the lowest burn rate as well as least soot production due to the fact that it has the lowest density. Two candles of each wax were purchased, five trials were performed on each group, for a total of ten burn rate measurements per wax type. Soot production was recorded qualitatively using photographs. The results did not support the hypothesis, instead the results suggested soy wax and beeswax had the lowest burn rate and least soot production. There was a statistically significant difference between paraffin and palm versus soy and beeswax, but not within either of the pairs. This experiment helped expand studies of candle wax and helped to determine what kind of wax material makes for safer candles.

Introduction

Candles have been part of human experience for thousands of years. The earliest documented use is attributed to ancient Egyptians, who, according to ancient inscriptions, used candles for ceremonial purposes (Blackman, 1924). Over the centuries, candles have evolved from a necessity used to see in the dark to a product used for decorative and ceremonial purposes.

Candles can be produced from several different waxes. Ancient candles were primarily from tallow, a material consisting of waxy white fat from the kidneys of farm animals (“tallow,” 2018). In the 19th century, Michel-Eugène Chevreul, a French chemist, produced stearic acid by separating fatty acids from glycerin in fat, allowing more efficient candles to be made. After Chevreul's finding, many others soon followed, leading to the discovery of what is now the most common wax: paraffin, a material formed from petroleum (“candle,” 2019). Beeswax is another commonly used wax, found in cell walls that bees use to make honeycombs (“beeswax,” 2019). There is existing research about paraffin, soy, and beeswax. However, recently, candles have been produced from a number of new materials, in particular, palm wax. Because it is relatively new, not many experiments have been performed to test its properties. This experiment will include palm wax candles and investigate their burn rate and soot production.

One of the dependent variables in this experiment is burn rate. Burn rate is defined as the amount of a material burned in a certain amount of time (often, grams per hour). The burn rate of candles may depend on the material they are made of. Understanding what type of candles have the lowest burn rate is important in order to know what candles to buy so that they will last longer. Longer-lasting candles are less wasteful for the environment and also end up being more affordable for consumers who have to replace fully burnt candles with new ones.

It is well known that density affects burn rate (e.g.: wood) (Osvaldova & Castellanos, 2019). This is because oxygen goes through materials of higher density less effectively. Applying this same concept to wax, the density of different waxes may affect their burn rate. Due to palm wax having the highest density, at 0.998 g/cm^3 , with beeswax at 0.950 g/cm^3 , and paraffin and soy wax both at 0.900 g/cm^3 , it is hypothesized to have the lowest burn rate (“Density of Palm wax,” n.d.) (Peggs, 2008), (“Density of soy wax,” n.d.).

The second dependent variable in this experiment is soot, a substance formed due to incomplete combustion of hydrocarbon flames. Soot can be harmful to human health as it is associated with a variety of breathing problems (Andersen et al., 2021). Therefore, knowing which candle produces the least soot will help to understand which candle wax material is better for consumers' health. The amount of soot produced by candles is a complex phenomenon, with one of the influences on soot production being wax material (Rezaei et al., 2002a). Different wax materials have different laminar smoke points. Laminar smoke point for candles is defined as the length of a wick-fed diffusion flame at the point of initial soot emission (. Candle flames that are higher than their laminar smoke point produce soot (Allan et al., 2009).

The purpose of this experiment is to test the effect of wax material on burn rate and soot production. With wax material being the independent variable, the four levels used in this experiment are paraffin, soy, palm, and beeswax.

Paraffin wax is the control in this experiment as it is the most commonly used and cheapest wax for candles today. Paraffin, which is also known as alkane, is a saturated compound which is described by the formula C_nH_{2n+2} , where n is the number of carbon atoms. Regular paraffins are unbranched straight-chain molecules (Fahim et al., 2010).

Soy wax, also known as partially hydrogenated soybean oil, is a biodegradable alternative to paraffin wax that has gained traction in recent years. It mainly consists of 11% palmitate, 12% stearate, 54% oleate, and 22% linoleate (Rezaei et al., 2002b).

Palm wax, or hydrogenated palm oil, is a less commonly used wax. It consists of 80% to 95% fatty acid, 0.5% to 20% palm-based fatty alcohol, and 0.5% to 10% palm glyceride (WEN HUEI, 2016).

Beeswax is a complex mixture consisting of more than 300 compounds: hydrocarbons, free fatty acids, esters of fatty acids and fatty alcohol, diesters and exogenous substances. It

was much more popular before the invention of cheaper and easier to produce waxes like paraffin (Fratini et al., 2016).

All of the candles used in the experiment will be 2 inches wide and 3 inches tall and will have cotton wicks of $\frac{1}{4}$ inch length. Additionally, room temperature and distance between candles will remain constant in order to prevent error. Burn rate will be measured quantitatively in grams per hour. Soot will be observed qualitatively with photos. The hypothesis is that palm wax candles will have the lowest burn rate because they have the highest density and palm wax candles will have the least amount of soot because they have the highest laminar smoke point. According to this reasoned hypothesis, palm candles would be the least wasteful and healthiest for the consumer as well as the environment.

Materials & Methods

Before starting this experiment, candles made of soy, palm, paraffin, and beeswax were purchased online (two candles of each wax). All these candles had a 2 in diameter and a cotton wick. Once the candles arrived, a ruler was used to measure 3 in height for all the candles, a pencil mark was made at 3in. Next, a knife was used to cut the candles to ensure that they were all the same height, 3in. Scissors and a ruler were then used to trim the wicks of all the candles to $\frac{1}{4}$ in. A sharpie was used to mark the bottom of each candle with its wax and group number (1 or 2). Each candle was placed on a Skyroku, model KS-486 electronic kitchen scale and the weight was recorded in grams to the nearest hundredth. Then, a tabletop was covered with aluminum foil and the group 1 candles were placed on the foil, 10in apart from one another. A lighter was used to light all of the candles and a timer was set for 1 hour. At the end of the 1 hour, all the candle flames were extinguished. A timer was set for 10 minutes to let the wax solidify. At the end of the 10 minutes, the wicks were once again trimmed to $\frac{1}{4}$ in and then the weight of each candle was recorded. This process of burning the candles and

weighing them was repeated 4 times for group 1 candles, for a total of 5 trials. Next, the same process occurred with group 2 candles, also 5 times.

Next, group 1 candles were once again placed on aluminum foil, 10in apart from one another. A glass Pyrex bowl with the top diameter being 8.5 in, the bottom diameter measuring 3.5 in, and the height measuring 3.5 in was also placed on the aluminum foil. A lighter was used to light the soy wax candle, the bowl was then immediately placed over the candle, with the bottom of the bowl towards the ceiling. A timer was set for 10 seconds, at the end of these 10 seconds the glass bowl was removed, the candle was immediately extinguished. An iPhone SE 2020 was used to take a picture of the soot on the bottom of the glass bowl. After the soot was photographed, the bottom of the bowl was wiped with a paper towel until the soot was no longer visible. Then, this process was repeated with each group 1 candle, 5 total times per candle. Next, this process was repeated with group 2 candles.

The results of this experiment were tabulated in Microsoft Excel, then QCd. Statistical analysis was conducted by first using an ANOVA test and then analyzed further by performing two t-tests. Analysis of soot production was not quantitative. Instead, soot formation was photographed and summarized in a data table.

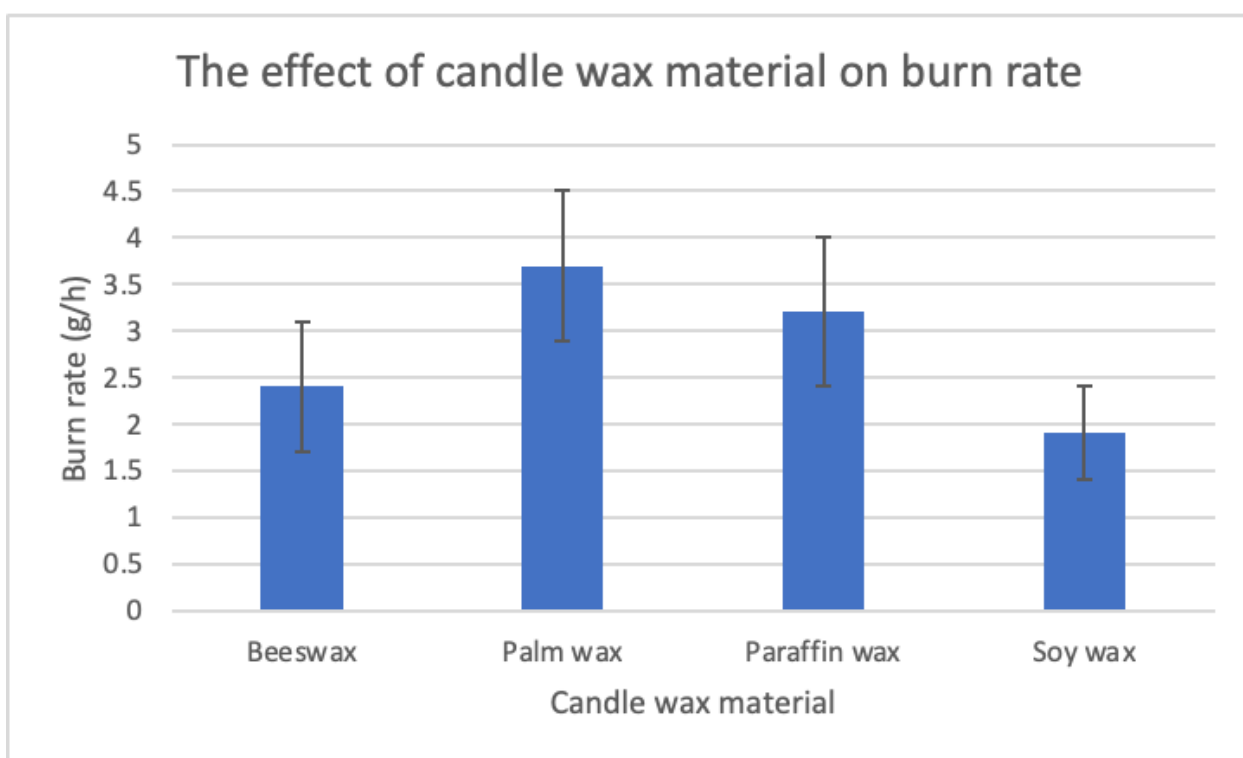
Throughout this process, an adult was present who had fire and knife safety training. Additionally, a fire extinguisher was present when any candles were lit. The surface that all the candles were placed on was covered completely with aluminum foil, a non-flammable material. After the experiment was completed, the aluminum foil was safely disposed of in the recycling. All candles were handled with caution and were not touched while burning and for 10 minutes after. Overall, the utmost attention was given to the safety of this experiment.

Results

Data Table #1 - The effect of candle wax material on burn rate (g/h)









































Candle wax material	Mean (g/h)	Standard Deviation (\pm)	Coefficient of Variation (st.d./mean)	Number of Trials
Beeswax	2.4	0.7	0.3	10
Palm wax	3.7	0.8	0.2	10
Paraffin wax	3.2	0.8	0.3	10
Soy wax	1.9	0.5	0.3	10

Graph #1 - The effect of candle wax material on burn rate


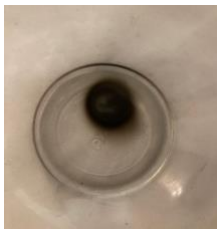
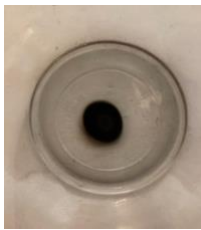



Data Table #2 - The effect of candle wax material on soot production (qualitative)

Candle wax	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10

material										
Bees wax										
Palm wax										
Paraffin wax										
Soy wax										

Data Table #3 - Typical Representation of the effect of candle wax material on soot production (qualitative)

Candle wax material	Beeswax	Palm wax	Paraffin wax	Soy wax
Typical Trial				

Data Table #4 - T-test Results for Burn Rate Analysis

Groups being compared	P-value
Palm wax and paraffin wax	0.26

Beeswax and soy wax	0.11
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The purpose of the experiment was to determine the candle wax materials with the lowest burn rate and the least soot production. As seen in Data Table #1 and Graph #1, soy wax had the lowest calculated mean at 1.9 g/h, with the lowest standard deviation of ± 0.5 . Palm wax had the highest calculated mean, at 3.7 g/h, with a standard deviation of ± 0.8 .

The data of these groups showed high precision, with all the coefficients of variations being less than 1. The trend in the data showed that as mean increased, so did standard deviation.

An ANOVA test was done to determine if a statistically significant difference existed among the means of the burn rate for beeswax, palm wax, paraffin wax, and soy wax. The calculated p-value was 3.96×10^{-5} , which is less than the critical value of 0.05, which means that the null hypothesis can be rejected.

As seen in Data Table #3, two t-tests were done to determine whether there was a statistically significant difference between the burn rates of groups. Both calculated p-values were greater than the critical value of 0.05, which means that there was not a significant difference between the groups palm and paraffin wax, as well as between the groups soy and beeswax.

Qualitative observations for the experiment included soot production (Data Table #2). Paraffin wax and palm wax were observed to produce much more soot than soy wax and beeswax. Although the soot produced from paraffin and palm wax is visibly more than from soy and beeswax, there was no visible significant difference between paraffin and palm wax. Soy and beeswax produced a much smaller amount of soot than paraffin and palm wax, but also did not have a visible significant difference between the two of them.

Conclusion

The purpose of this experiment was to determine the effect of wax material on burn rate and soot production. It was hypothesized that burn rates of different wax materials would be different and that palm wax would have the lowest burn rate and the least soot production.

The research conducted suggested that density can affect burn rate of materials, as seen with wood (Osvaldova & Castellanos, 2019). This research was then used to formulate a hypothesis, based on the idea that the wax with the highest density would burn the slowest and thus have the lowest burn rate. This hypothesis was not supported by the results of the experiment. The results suggested that soy wax and beeswax had the lowest burn rate and soy wax and beeswax had the lowest soot production. Although the hypothesis was not supported by the data, the data did show a correlation between the burn rate and soot production of waxes. Paraffin wax and palm wax, the two waxes with the highest burn rates, also showed the most soot production based on qualitative observations.

Even though the research hypothesis was not supported, there was a statistically significant difference in burn rates between the means of the four groups: beeswax, palm wax, paraffin wax, and soy wax. The null hypothesis was that candle wax material would have no effect on burn rate. The null hypothesis was rejected after an ANOVA test was performed.

As discussed earlier, the results found in this experiment as well as in future studies will help buyers determine what kind of candles to buy in order to have long-lasting candles. Additionally, buyers will be able to avoid candles that produce large amounts of soot and are therefore harmful to the environment as well as to human health, since soot is associated with breathing problems (Andersen et al., 2021). This shows that the qualitative information found in this experiment is important.

The results obtained on burn rates may mean that the density is not important for the burn rate, but there are some uncertainties related to this experiment. The main uncertainty was that the name of the wax material for a candle does not guarantee that the candle

manufacturer did not add significant amounts of other materials for economic or production reasons. These other materials may affect the burn rate of the wax, resulting in random error. Another source of uncertainty may be a potential use of different wick materials by different candle manufacturers.

A limitation of the analysis was that there were only two candles of each wax tested, both of which being from the same manufacturer. The low number of candles tested may also not be representative of candles from other manufacturers.

Given these uncertainties and still significant differences between the burn rates of different wax materials shown in the experiment, further research is needed. Further improvement of results could be accomplished by using pure wax materials and standardized wicks as well as a greater number of trials. Together, these changes would allow for more reliable results on burn rates and soot production.

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